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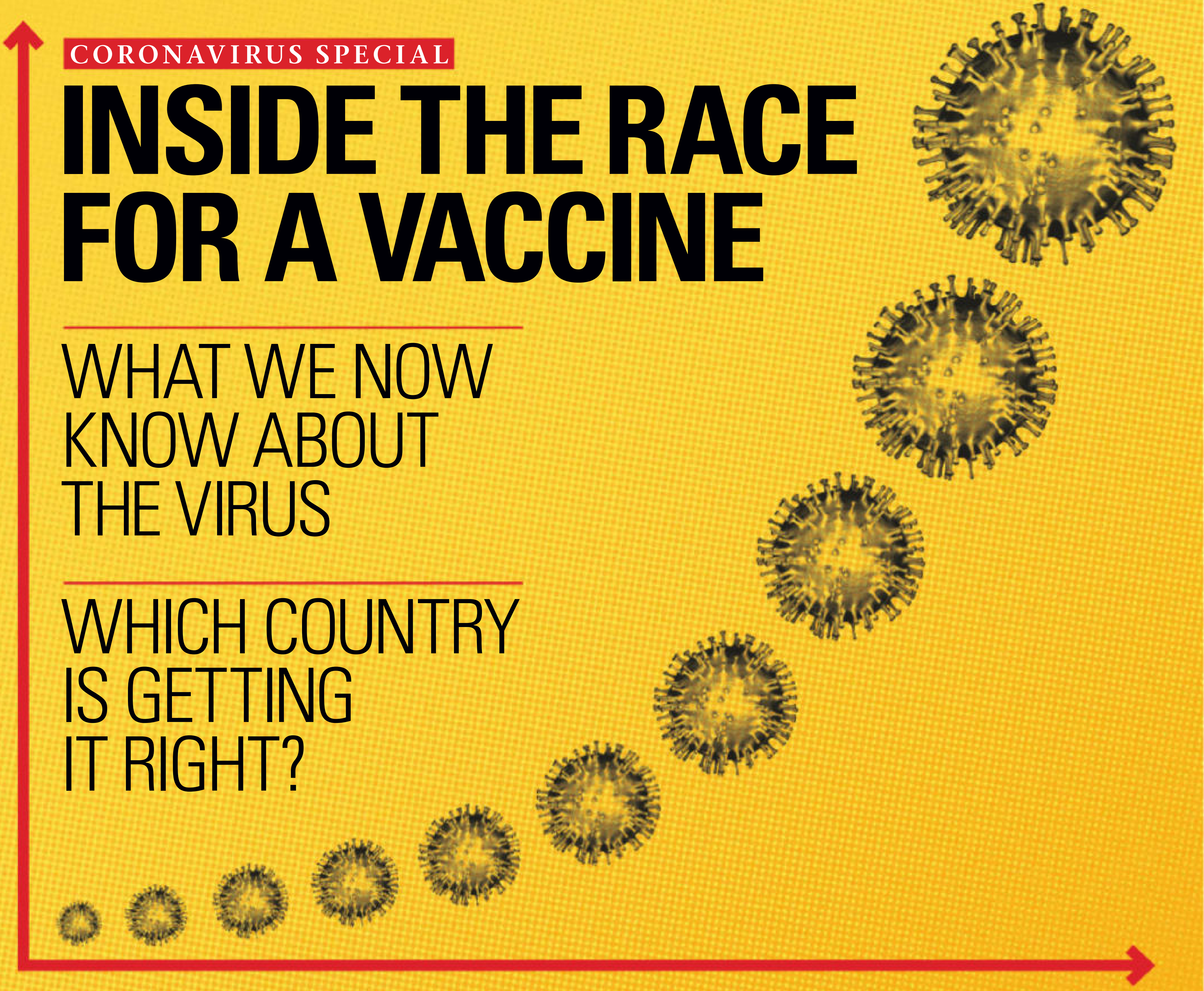

CORONAVIRUS SPECIAL

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The big interview

This week's issue

Dear reader,
Firstly, as ever, thank you for reading.

Secondly, as will be obvious to you, the emergence of this novel coronavirus has led us into uncertain times, and alongside every business and institution in the world, we are having to plan, on the basis of the best data we have access to, for what could be difficult times ahead.

New Scientist already has plans in place to keep its staff as safe as possible, and to ensure the smooth production of our journalism in the event that public life is curtailed even further in the days or weeks ahead. We are also talking to all our colleagues in our publishing and supply chain to try to ensure the continued production of the magazine in those circumstances.

We must also plan for the possibility, however unlikely, that in the next few weeks we may not be able to get a magazine published and delivered to both newsstands and subscribers because of some unforeseen circumstances.

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All the very best to you,
Emily Wilson, Editor

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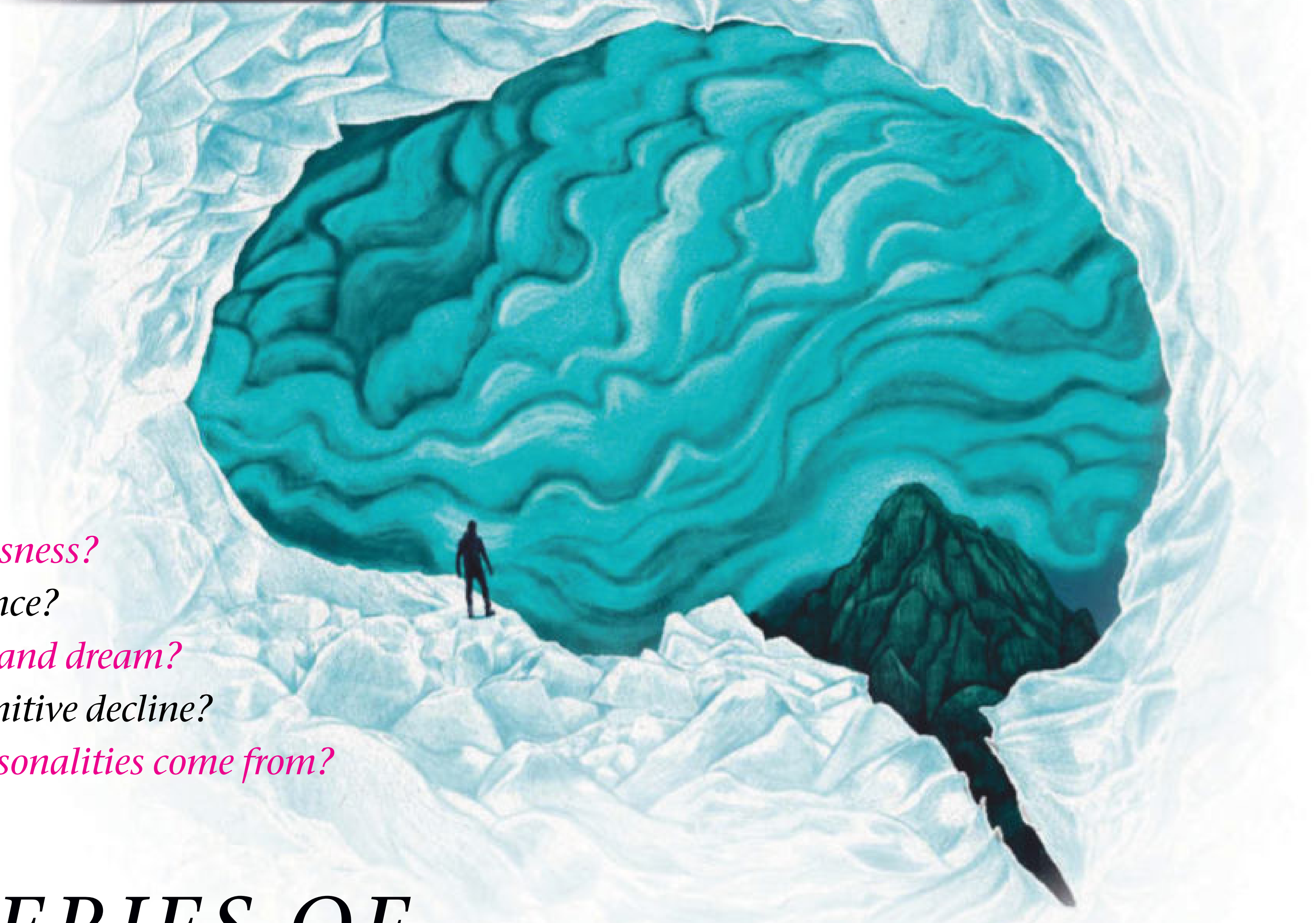

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Testing times

We will understand this pandemic only when we have more data

ABRUPTLY, the world is in lockdown. Many of the countries that aren't there yet will be there shortly.

In the UK, advice to stay at home and government restrictions have arrived more slowly than in neighbouring nations. That has sparked criticism from a number of scientists outside the government science advisory team. Such disagreement has been confusing for a public so often encouraged to trust the experts, especially in the middle of this pandemic. Who do they trust when the experts disagree?

The fact is: no one knows what the correct course of action is. Epidemiologists have a saying: "If you've seen one pandemic, you've seen one pandemic."

We are in an entirely novel situation, not least because coronavirus is so notably different from flu.

We will understand this pandemic only when we have more data. That is why, as countries scramble to boost their intensive care capacity, they should also listen to the advice coming from the World Health Organization to "test, test, test". As WHO assistant director general Bruce Aylward tells us in this issue (see page 8): "To actually stop the virus, [China] had to do rapid testing of any suspect case, immediate isolation of anyone who was a confirmed or suspected case, and then quarantine the close contacts for 14 days so that they could figure out if any were infected. Those were the measures that stopped transmission in China, not the big travel restrictions and lockdowns."

> "Many people are doing everything they can to limit the spread of this virus and support the most vulnerable people"

There are hard days ahead. Aylward explains that lockdown is the hard part, and effectively isolating all covid-19 cases is the really hard part. Our feature on the race for a vaccine (see page 44) reinforces the fact that there will be no quick or neat solutions to this crisis.

We are all adjusting to our new lives in the time of the coronavirus, but signs of strong community spirit are already emerging. Many people are doing everything they can, not only to limit the spread of this virus, but also to support the most vulnerable people in their communities. This is a war in which we really can all do our bit. ▮

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UK government advice is to avoid all non-essential contact and travel

TOLGA AKMEN/AFP VIA GETTY IMAGES

Covid-19 escalates

WHO calls for more testing as countries worldwide bring in strict measures to slow new coronavirus's spread, reports **Adam Vaughan**

THE total number of coronavirus cases and deaths outside China has now overtaken those within the country. Around the world, countries have closed borders and ramped up social distancing measures.

When *New Scientist* went to press, there had been more than 180,000 confirmed cases and more than 7000 deaths globally. China has still had the highest number of cases, followed by Italy and Iran. Spain is now fourth, having overtaken South Korea.

Many countries are imposing border restrictions to reduce the spread of the virus, including Canada, Costa Rica and Tunisia. The European Union closed its external borders on Tuesday.

The World Health Organization's director general Tedros Adhanom Ghebreyesus said on Monday that there has been a "rapid escalation" of cases in the past week. He said that while governments had increased efforts to slow the outbreak, they weren't doing enough, and called for continued testing.

"You cannot fight a fire blindfolded. And we cannot stop this pandemic if we don't know who is infected. We have a simple message for all countries: test, test, test. Test every suspected case," he told journalists at a briefing.

His comments came as the UK stepped up its response, with prime minister Boris Johnson announcing a "national fightback" against the virus. Guidance included avoiding unnecessary social contact, ending non-essential travel and other social distancing steps. However, the measures are voluntary and stop short of many of the country's European neighbours, several of which have closed schools and instituted mandatory lockdowns.

It is thought that a new modelling study by a team led by Neil Ferguson at Imperial College London may have influenced the UK's new measures. The team's analysis, which the UK government told *New Scientist* had been discussed at meetings informing the new policies, says previous estimates of predicted demand for intensive care units in hospitals had been doubled because of data coming in from Italy and the UK.

Intensive care is still likely to be overwhelmed even with the new steps, with demand likely to be eight times higher than availability even in the most optimistic scenario, the team warned.

21

Number of new, confirmed cases in China on 16 March

France is taking a more extreme approach, and from Tuesday the whole country's population must "stay at home" for anything other than food shopping, medical supplies or exercise. Flouting the rules risk fines of up to €135 (£121).

In the US on Monday, the White House issued guidelines as part of its "15 days to slow the virus" campaign. Chief among them is a ban on mass gatherings, with people told to avoid gathering in groups of more than 10, and to avoid bars, restaurants and unnecessary travel.

Australia, which has had relatively few cases so far, told Australians to come home from abroad and is weighing up stronger measures.

New cases in China, where the virus originated, have stayed low in recent days. The country confirmed 21 cases on Monday, 20 of which were people arriving from abroad.

South Korea, which was also hit early by the virus but has tested at a greater rate than any other country, had its third day running with fewer new cases, at 84 on Monday. ▮

The latest coronavirus news online
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Interview: Bruce Aylward

The countries getting it right

The world can learn lessons from how China, South Korea and Singapore have handled covid-19, the WHO's Bruce Aylward tells **Jessica Hamzelou**

LAST month, the World Health Organization's assistant director general Bruce Aylward set out to learn more about China's response to the covid-19 outbreak and generate recommendations for China and other countries. He told Jessica Hamzelou what we have learned so far.

Jessica Hamzelou: Cases in China are declining – we are now only seeing a handful of new reported cases every day. Does China have the virus under control?
Bruce Aylward: It has absolutely turned it around. [But] governors, mayors and others that I talked to in China would never say things were "under control". When I asked them if they felt good about falling cases, they said no. They said they were building more beds and buying more ventilators because they were worried that they might never get something like this – a new virus that we don't understand – under control.

Now they are planning to open up all the travel restrictions, get people back to work and get students back to school. But their feeling was that this is going to remain in the population and raise its ugly head, and they have to be able to respond rapidly.

How did China get to this point?
China did something that most other countries would not even have tried, and many people thought would have been impossible. It used fundamental public health approaches – such as case finding and contact tracing – to stop a respiratory virus.

That seemed almost impossible as a premise because respiratory viruses transmit so effectively and efficiently – typically the only way you can stop them is with a vaccine or pharmaceutical treatment. What China did provides a lesson for infectious disease epidemiologists.

Bruce Aylward has been studying the effects of China's response

FABRICE COFFRINI/AFP VIA GETTY IMAGES

Does that mean China's extreme lockdowns were the right way to go?
Everyone always starts at the wrong end of the China response. The first thing it did was try to prevent the spread as much as it could, and make sure people knew about the disease and how to get tested.

To actually stop the virus, it had to do rapid testing of any suspect case, immediate isolation of anyone who was a confirmed or suspected case, and then quarantine the close contacts for 14 days so that they could figure out if any were infected. Those were the measures that stopped transmission in China, not the big travel restrictions and lockdowns.

14%

Roughly how many people in South Korea are 65 or older

Stopping the movement of people doesn't stop the virus jumping from person to person, it just prevents those people from moving to other places. The travel restrictions and lockdowns were to give them time to get the other things in place and actually stop transmission.

When I spoke to Italy the other day, they said: "We've got these lockdowns in place." I said: "Great, you've done the hard part, now you have to do the really hard part, and that is making sure the cases are effectively isolated."

Italy is the most affected country in Europe. What's happening there?
What's happening in Italy, and in many other countries in Europe, is that they are treating the mild cases at home. In some countries they are not even testing them. They are saying if you have a cough and high fever, stay at home.

But the problem then is that [people] don't know that they have the disease, they haven't had it confirmed. After a couple of days people get bored, go out for a walk and go shopping and get other people infected. If you know you are infected you are more likely to isolate yourself.

Generally in a population, around 60 to 80 per cent of those affected are going to have mild or moderate disease. If those people are all out of hospital, most of your cases are at home, but not isolated. In China, they found that didn't work. They had to get them isolated in hospitals or dormitories or stadiums. The main goal was to keep them from getting bored.

Which countries have responded well to the outbreak?
There are lots. Look at South Korea – it has been pretty rigorous about testing all the suspect cases and finding all the contacts. In the past couple of days, we have seen that, instead of that relentless upward creep in cases, it seems to have turned a corner, which is positive.

Singapore is another country that has been hit with importations again and again, and they are jumping on them, tracing all the cases, tracing all the contacts, professionally isolating them all. It seems to be doing pretty well, even though it has got relatively big numbers.

Canada had importations into four or five different provinces. And in almost all of those it has been able to keep the numbers fairly low, following a very similar rapid test approach. And in all those places, it's very easy to get tested as well.

Do you think these countries have learned lessons from other, past outbreaks?
Oh absolutely. When you look at Singapore, South Korea, China – why are they so aggressive in terms of case finding and contact tracing for coronavirus? Well they

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were all hit by SARS. Similarly, if you look at Canada, it had a big SARS outbreak back in 2003, with hundreds of cases.

[These countries] saw the devastation a coronavirus can cause – they jumped right on it.

Why has the case fatality rate been lower in South Korea than in other countries?
It has a relatively young population. The population aged over 65 in South Korea is something like 14 per cent – half that of Japan and much lower than Italy. A case fatality rate of around 1 per cent – close to what we are seeing in South Korea now – is what we see in a young population. But the case fatality rate has been creeping up over time. The thing that I would remember, even right now in South Korea, is that [the fatality rate] is still tenfold higher than seasonal flu.

A covid-19 testing booth outside Yangji hospital in Seoul, South Korea

ED JONES/AFP VIA GETTY IMAGES

Is that why it has been so bad in Italy, because the population is older?
We are not sure. I saw some data from the north [of Italy] that suggests around one-third of cases are being managed at home. Some of the milder cases just aren't being tested and officially diagnosed. That's part of the problem.

The second is the older population. The third is it is also very early in their outbreak, and that can sometimes be where you see higher mortality among older people, and it distorts the picture.

What do you think of the UK, which hasn't been taking as strong measures as some countries?
People have different reasons for taking different measures at different times in an outbreak. Chris [Whitty, chief medical adviser to the UK] is one of the brightest, most sensible and careful people I know. I'm not going to second-guess anybody at this time.

How effective is closing schools?
That's a tough one. The data [on this is] for a different disease – it's for flu. Kids get these rip-roaring flus, and the whole classroom gets sick. The kids get their families infected. Parents have to stay at home with the kids, and then they get sick, go to work and infect others.

"Lockdown is the hard part. Making sure cases are effectively isolated is the really hard part"

But one of the curious things with [covid-19] is that we have not seen school outbreaks. I talked to my colleagues in South Korea, in China, in Italy, everywhere – no one has seen school outbreaks. They have seen situations where a teacher is infected and they have infected kids, but that is different to the kids all getting each other infected.

When you talk about school closures, you want to know, is it going to reduce the intensity of transmission? We know that it probably won't reduce the number of sick people very much, because not many kids get sick. But what we don't know is, are kids getting infected and we just can't see it? And if they are, are they carrying it back to their families? Even there we don't have a lot of data to suggest that kids are infecting their families. So as a result, countries have done things differently.

There is a chance that when cases decline in countries and restrictions loosen, we will see more infections. What happens then?
China decided that it cannot afford to wait for cases to go to absolute zero – not knowing if they ever will – so it decided to strengthen its whole system so that it could live with the disease if it had to. It is building additional capacity to isolate people, and it is building additional ventilators. It is planning to be able to manage low-level disease and prevent large outbreaks. It's a very sensible way to plan.

It's wishful thinking to think that the virus is going to disappear altogether. People keep saying that maybe in the warm season it will. Last time I checked, Singapore was very warm, and it's roaring away there.

Have you seen anything like this outbreak before?
As soon as you [compare the disease to others], you are dead. This is a new disease. Respect it and learn as it evolves. The more you lean on your old [experiences], the more mistakes you are going to make. ▮

Aylward spoke to New Scientist *on 13 March. The interview has been edited for length and clarity.*

Virology

Public enemy number one

The new coronavirus is no small threat, but we are starting to understand how it works, reports **Michael Marshall**

THE covid-19 virus is humanity's newest foe, with the potential to prematurely end millions of lives. To control this new coronavirus, we need to understand it. Labs around the world are now working around the clock in a bid to know their enemy.

Three crucial questions are occupying virologists. What makes the new virus so good at infecting people? How does it reproduce so quickly once it is inside us? And why doesn't the virus cause symptoms straight away, allowing it to spread undetected? The answers will suggest ways to treat the disease and develop vaccines (see "Race for a vaccine", page 44). Clues can be found in the virus's biology.

Like all viruses, the covid-19 virus must infect living cells in order to reproduce. Each virus strives to burrow into a cell and take over its internal machinery, repurposing it to build the components of new viruses. These new viruses are then ejected from the cell, where they can infect more cells – either in the same body, or in a new host.

The covid-19 virus belongs to a family of coronaviruses, which are fairly intricate as viruses go. Each coronavirus has at its core a strand of RNA, a molecule similar to DNA that carries the virus's genes. Around this is a protein shell, which is surrounded by two layers of molecules called lipids. This outer membrane is dotted with proteins, some of which stick out like the spikes on a sea urchin.

The spike proteins are critical, says Michael Letko at the National Institute of Allergy and Infectious Diseases in Montana. They act as an anchor for the virus, attaching to a protein on the outside of a cell.

In a study published on 9 March, researchers led by Alexandra Walls at the University of Washington in Seattle used electron microscopy to determine the atomic structure of the spike protein on the covid-19 virus (*Cell*, doi.org/dpvh). With this information, inhibitor drugs can now be designed to block it from attaching to a human cell.

"The spike proteins are crucial. They act as an anchor for the virus to attach to the cell"

Another approach is to target the proteins on human cells that the spike proteins latch on to. To do that, we first have to know what they are. One candidate for this method is the attachment point used by the closely related SARS virus: angiotensin-converting enzyme 2 (ACE2). In late February, Letko's team became one of several to confirm that the new coronavirus's spike protein also binds to ACE2 (*Nature Microbiology*, doi.org/dpvk).

Letko says a role for ACE2 makes sense. "It's expressed in the lung and it's expressed in the gastrointestinal tract, so that may partially explain why the virus is able to infect those places."

However, the virus doesn't simply attach itself to ACE2. The spike protein first has to split itself, and it harnesses human cell proteins to do this. One protein that is co-opted in this way is transmembrane protease serine 2 (TMPRSS2), which was identified by two studies published in March (*Cell*, doi.org/ggnq74; *PNAS*, doi.org/dpvm). Walls's team found that a second protein called furin can also split the spike protein.

"These can also be targets," says Rolf Hilgenfeld at the University of Lübeck in Germany. If we can block these human proteins with drugs, the virus wouldn't be able to get into the host cell – although the proteins' normal functions would also be interrupted, potentially causing side effects.

The virus's entry into cells can also be interrupted by a protein called lymphocyte antigen 6E (LY6E), which is involved in our immune response. In a study published on 7 March, Stephanie Pfänder at Ruhr-University Bochum in Germany and her colleagues showed that LY6E stops many coronaviruses, including the covid-19 virus, from entering cells, and that mice lacking LY6E are more vulnerable to infection than those with it (bioRxiv, doi.org/dpvn).

She says that if we find out what this protein does, it might be possible to mimic it with a drug, and it may be able to fight against infection by many coronaviruses. "Having a [coronavirus] inhibitor would obviously be of great

No, this virus isn't a bioweapon

New diseases have emerged throughout human history, and we have seen two major coronavirus outbreaks in the last two decades: SARS and MERS. So we shouldn't be surprised by the arrival of the covid-19 virus.

However, rumours on social media suggest that the outbreak was human-made. Some say the virus leaked from a Chinese lab studying coronaviruses. Others suggest the virus was engineered to spread among humans.

Even the most secure laboratories do sometimes have accidents, and a human-engineered pandemic has been identified as a possible risk to our civilisation, but there is no good evidence that either has happened.

Many similar viruses are found in wild bats, and it seems likely that is the origin of this one, probably via an intermediate host. Similarly, we know that both SARS and MERS came from bats, so there is no reason to invoke a laboratory accident.

Researchers led by Shan-Lu Liu at the Ohio State University say there is "no credible evidence" of genetic engineering (*Emerging Microbes & Infections*, doi.org/dpvw). The virus's genome has been sequenced, and if it had been altered, we would expect to see signs of inserted gene sequences. But we now know the points that differ from bat viruses are scattered in a fairly random way, just as they would be if the new virus had evolved naturally.

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Labs around the world are racing to understand the new coronavirus

SYLVAIN LEFEVRE/GETTY IMAGES

importance also to help against future outbreaks and not only the current pandemic," she says.

Stopping a virus entering cells is one thing, but if a person is already infected it may not help. In that case, we need a way to interfere with a virus's ability to copy itself inside cells.

There are two obvious attack points. To proliferate, the virus has to build proteins, and copy its RNA genome. The proteins are made first. When the virus's RNA enters an infected cell, the host machinery reads the virus's genes and strings together two large "polyproteins" containing several viral proteins. Some of these are enzymes called proteases, which first cut themselves out of the polyprotein, and then cut out other proteins, freeing them to carry out their functions.

"When you interrupt that, the virus cannot replicate," says Hilgenfeld. His team has determined the atomic structure of the main protease (bioRxiv, doi.org/dpvp) and identified substances that bind to it (bioRxiv, doi.org/dpvq).

His group has been developing an inhibitor for the main proteases of coronaviruses and a related group called enteroviruses in the hope that such a drug would be broadly applicable enough to appeal to a drug company. The researchers have now modified them so that they also work on the covid-19 virus and showed that the resulting drug works on single cells. However, there are still many more stages of testing before the drug could be used in people with covid-19.

The other option is to stop the virus copying its genome. This is done by another viral protein, the RNA-dependent RNA polymerase (RdRP). Most RNA viruses don't check for errors when copying their genomes, so they can be blocked by introducing modified RNA building blocks, which the RdRP will incorporate "if the virus is stupid enough", says Hilgenfeld.

Unfortunately, coronaviruses like the covid-19 virus have a proofreading enzyme called exonuclease, which removes the modified RNA components and allows copying to continue. "Many of the existing RdRP inhibitors do not help against coronaviruses," says Hilgenfeld.

Nevertheless, in a preliminary step, researchers led by Tai Yang at Chengdu Medical College in China have identified seven chemicals that calculations suggest might bind to it (*Preprints*, doi.org/dpvs). Meanwhile, a drug called remdesivir, originally developed to treat Ebola, has also shown promise as an RdRP inhibitor.

In the long term, we need to know why this virus is so good at spreading. "It's the undetected spread that's contributed a lot to the severity of this outbreak," says Letko.

The key to the virus's spread is its ability to reproduce inside our bodies for days without triggering our immune response. The most recognisable symptoms of covid-19 – fever and coughing – are actually due to our immune system fighting back – but the virus delays this with extra genes it carries.

2

The number of outer lipid layers that protect the covid-19 virus

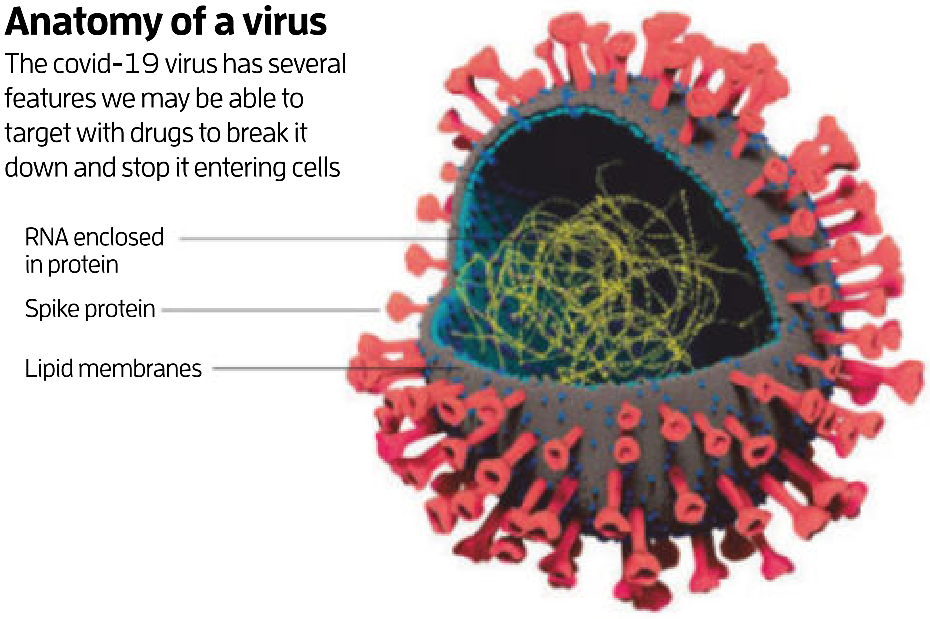
These "non-structural genes" code for proteins that interfere with our immune system. When a cell becomes infected, an alarm system called the interferon pathway is triggered. "The virus has proteins to interfere with that pathway," says Letko.

Some of the non-structural genes of the covid-19 virus look similar to known genes, so we can make an educated guess about their function. "But some of the stuff we really don't have a firm grasp on," says Letko.

In the immediate future, understanding these proteins may not help us slow the outbreak, but it could help us build antiviral drugs in the future. ▮

Anatomy of a virus

The covid-19 virus has several features we may be able to target with drugs to break it down and stop it entering cells



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Solar system

Early Mars may have had right conditions for RNA to start life

Michael Marshall

IT IS possible that life started on Mars billions of years ago in certain regions where conditions were unusually hospitable.

If life ever existed on Mars, it is conceivable that it began with RNA, which is similar to the DNA that carries our genes. Many scientists suspect that RNA played a key role in life's beginnings on Earth, and some even argue that the first life was based solely on RNA.

> "Mars is currently too frigid for much liquid water, but it may have had running water billions of years ago"

To see if that could have played out on Mars, Angel Mojarro at the Massachusetts Institute of Technology and his colleagues simulated the early environment of Mars. Its current frigid climate allows for little liquid water, but there is evidence that Mars had running water billions of years ago.

Mojarro's team placed RNA-like molecules in water that contained dissolved metals and other chemicals. These solutions mimic water on early Mars, which would have contained metals leached out of rocks, and would have been altered by atmospheric chemistry.

They tracked how long the molecules lasted before breaking apart. The RNA-like molecules were most stable in mildly acidic water containing magnesium ions, which would be expected if the water were resting on basalt: a rock that forms when lava from a volcano cools (bioRxiv, doi.org/dprt).

The authors say that means Martian life developing from RNA is plausible. Jack Mustard at Brown University in Rhode Island says the results should be treated with caution, because there are "very large uncertainties" about what conditions on Mars were really like when the planet was young.

Air pollution

AI forecasts harmful particle levels in Beijing

Adam Vaughan

DAVID GOURHAN/ALAMY

Some Chinese cities have high levels of air pollution

MANY cities in China normally experience dangerous levels of PM2.5, the tiny particulate matter linked to some of the worst health effects from air pollution. Now it seems artificial intelligence could help us avoid the stuff.

Most air pollution forecasts are based on models that use maps of annual average air pollution emissions, the application of weather models and assumptions about chemical reactions. These can't account for unforeseeable events, such as extra pollution from a traffic jam or an accidental chemical release.

Baihua Li at Loughborough University, UK, and her colleagues took a different approach to see whether AI could do a better job. They used machine learning to train a model for predicting PM2.5 levels on three years' worth of data from Beijing, chosen due to the number of Chinese cities with a PM2.5 problem.

Around 26,000 data points were used, including average PM2.5 readings from four roadside pollution sensors and historical weather data. Li says the resulting forecasts for the locations near these sensors were highly accurate, based on how closely they matched historical observations. One hour ahead, they were 95 per cent accurate, falling to 85 per cent for 6 hours ahead.

Using this approach also helped the researchers tease out which factors were the most important in predicting dirty air. Sunlight, air pressure, the season and wind speed were found to be key. Wind blowing from the north-west often indicated a bad pollution episode was likely, perhaps due to the industrial facilities to the north-west of Beijing.

PM2.5

Tiny particulate matter that can cause health problems

Unlike most air quality forecasts, which usually warn the public of a single likely level of pollution for their area, Li's system provides a likely range of PM2.5 levels to give an idea of the uncertainty. The model could be adapted for other cities affected by PM2.5, such as Delhi, provided it is trained with local data. The developed system is going to be tested in Shenzhen, China, using live data from pollution sensors.

"If we can warn people of impending smog, then they can take steps to protect themselves," says Gary Fuller at King's College London. He says machine learning could be useful where data on pollution sources is lacking. "Alerting systems around the world, such as that run by the UK Met Office, rely on understanding air pollution sources in a city. Data-driven models, such as this example for Beijing, can be used where the knowledge of local sources is sparse or uncertain."

The coronavirus outbreak means that air pollution in China is currently down, as people are staying at home. Satellite analysis reveals that levels of PM2.5 in February 2020 were down 20 to 30 per cent versus previous years.

A separate study by the European Environment Agency (EEA) last Thursday concluded that relatively low-cost air pollution sensors used by individuals and groups can, when used well, provide data meeting the same quality standards required of official roadside monitors. The EEA said such citizen science initiatives could "help raise public awareness of air quality issues in communities and trigger behavioural changes to reduce emissions".

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Conservation

Shrinking Amazon

Weak law enforcement may be behind record deforestation levels

Adam Vaughan

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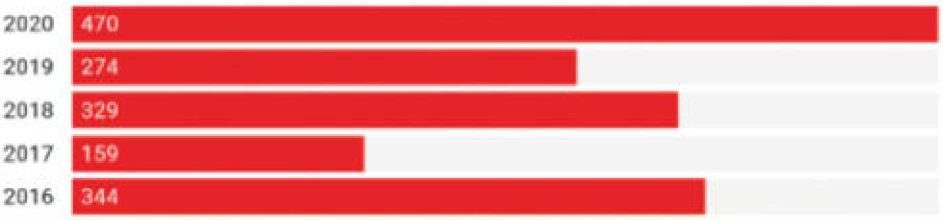
Trees are being cut down to make room to develop the Amazon

Area deforested in January and February in square kilometres



Source: INPE • Created with Datawrapper

DEFORESTATION of the Amazon has continued at record levels this year, leading observers to warn that the rainforest is disappearing faster than ever before.

Under Brazilian president Jair Bolsonaro, who has encouraged clearance of parts of the Amazon for development, the area of rainforest destroyed between August 2018 and July 2019 jumped by nearly 30 per cent to its highest level in a decade.

With official data from Brazil's National Institute for Space Research (INPE) now in for January and February 2020, it is clear there has been no let-up for the Amazon. A 470-square-kilometre area, around the size of Andorra, was lost in this period, up about 70 per cent on a year ago.

The new figures are particularly troubling because this time of year usually sees relatively little loss, as the rainforest is still in the rainy season and it is harder to set fires.

"The data shows a trend and it is likely that in 2020 we will see a continued increase in deforestation as the year progresses, especially as we move towards the dry season, when deforestation peaks," says Erika Berenguer at the University of Oxford.

The area of forest lost is the largest reported in a January and February period since 2015, which is when INPE introduced a more powerful, high-resolution version of its satellite deforestation alert system, DETER.

"The trend indicated by the DETER system is very worrying. It has shown a continued rate of increase of deforestation in comparison to one year ago," says Carlos Nobre at the University of São Paulo, Brazil.

The rate is even higher than it was at the beginning of 2016, when the Amazon was severely affected by a mega-drought driven by the El Niño climate phenomenon. Deforestation tends to rise at times of drought.

This time, the only likely explanation is that illegal loggers have been emboldened by a lack of law enforcement, says Nobre. "The increase in the rates of deforestation cannot be explained by any climatic factor. It is likely to be due solely to the sense of impunity of the environmental criminals that law enforcement is very weak and absent."

The preliminary data from DETER means official annual deforestation figures for 2020, counted from August 2019 to July 2020, are likely to eclipse those of last year, which saw the highest losses since 2008, says Berenguer.

"Unless there is a strong governmental response to the increase in deforestation, 2020 is panning out to be even worse than 2019," she says. ▮

Health

Type 1 diabetes may come in two different forms

THERE could be more kinds of type 1 diabetes than we thought, a finding that might lead to changes in treatment.

In type 1 diabetes, the immune system attacks the pancreas cells that make the sugar-regulating hormone insulin.

The age someone is diagnosed with type 1 diabetes seems to be linked to the severity of their symptoms. "A child diagnosed before the age of 5 is likely to have a more severe form of disease than someone over 30," says Sarah Richardson at the University of Exeter, UK.

To find out why, she and her colleagues looked at 32 pancreas samples from young people with diabetes who died in the 1950s. They found two distinct categories. In the first, some pancreases didn't appear to make insulin properly and experienced a stronger immune system attack. In the other, the samples contained fewer immune cells and there were also signs that the pancreases were better at making insulin.

The team then looked at blood samples from 171 people who had been diagnosed with type 1 diabetes before they turned 30, and found they seemed to fall into the same two categories. People whose type 1 diabetes involved poor insulin production and a stronger immune attack tended to be under the age of 7, while those diagnosed at 13 and up usually fell into the category of people whose pancreases contained fewer immune cells. Those aged between 7 and 12 when diagnosed could fall in either category (*Diabetologia*, doi.org/dpvj).

"The two groups both need insulin. But they may have got there through a different pathway"

For now, "the outcome is the same: both need insulin. But they may have got there through a different pathway", says Richardson. In future, she thinks they may need different treatments. ▮

Jessica Hamzelou

Technology

AI nudges guests and staff to cut hotel energy use

Frederick O'Brien

AN ARTIFICIALLY intelligent eco-assistant can persuade hotel guests and staff to reduce electricity use by up to a third.

My Green Butler is a cloud-based system that monitors equipment connected to the internet and gives regular, environmentally friendly tips, such as suggesting guests switch off air conditioning units at night or recommending that they take shorter showers.

Via computers, tablet devices or printouts, the system also advises staff to modify behaviour, such as lowering the temperature in rooms when they aren't in use. The more the system is used, the more tailored its recommendations become, allowing it to feed back on what actions have the most impact.

"Encouraging people to follow suggestions is much easier than going up to them and saying, 'Save the planet'," says Christopher Warren, founder of My Green Butler, which is based in Australia.

The system has been trialled at 10 sites across the UK, Australia, and France, including at two Disneyland Paris properties. Last month, My Green Butler reported that its technology can lead to 20 per cent cuts in gas use and a 33 per cent decline in electricity use.

Guests can choose whether they want to use the system, and an estimated 5000 people have opted in so far. Response to the AI has been largely positive, with only one of the 10 trial sites reporting people opting out.

Elaine Weidman-Grunewald at the AI Sustainability Center, a think tank in Sweden, says that the hotel assistant "shows great potential to be an environmental helper", but that caution is needed over data collection, storage and use.

My Green Butler says it complies with the European Union's data privacy regulations and that the company doesn't sell data. ▮

Astronomy

Stellar flares could make Proxima b more habitable

Abigail Beall

AS IT orbits the small red dwarf star Proxima Centauri, the nearest system to ours, an exoplanet called Proxima b is pummelled by nearly constant stellar flares and cosmic rays. Until now, it was thought these might be damaging to potential life, but new research suggests the flares could actually help make the planet more habitable.

Markus Scheucher at the Technical University of Berlin in Germany and his colleagues modelled how energetic particles from stellar flares and cosmic rays would affect the temperature of Proxima b.

Because it orbits such a small star, Proxima b only gets 65 per cent of the energy that we receive from our sun, despite orbiting at one-twentieth of the distance that we do.

"An otherwise likely too cold planet could actually experience habitable surface temperatures if [it] is actually Earth-like and is frequently bombarded by stellar energetic particles," he says.

The stellar flares, along with cosmic rays, batter the planet with hydrogen nuclei. This causes the production of hydroxide in the atmosphere, which reacts with methane to create carbon dioxide and water.

That process limits methane in the atmosphere, which could otherwise absorb solar radiation and lead to an anti-greenhouse effect, cooling the planet as it would be unable to trap heat from the star (arxiv.org/abs/2003.02036).

85%

Stars in the Milky Way that are red dwarfs, like Proxima Centauri

This type of cooling happens in our own solar system. For example, Saturn's moon Titan has a methane-rich atmosphere, where 90 per cent of the energy from the sun is absorbed in the upper atmosphere, so it doesn't reach the surface.

The study provides a new way to think about planets orbiting active stars like Proxima Centauri. Red dwarfs are the most common stars in the universe, making up 85 per cent of those in the Milky Way, and many of the Earth-sized exoplanets discovered in recent years are orbiting them.

"This is good for planets such as Proxima Centauri b, but not necessarily for those closer to their star," says Abel Méndez at the University of Puerto Rico at Arecibo. Yet for those in the sweet spot, stellar flares might not be a bad thing after all.

"There are other possible good things about flares," says Méndez. "For example, they might provide enough energy to create basic molecules necessary for the origin of life."

A study in 2018 found that UV light from stars could help form precursors to RNA, a process called abiogenesis.

Yet detecting life on a planet that is four light years away, like Proxima b, would be tricky. Still, it is possible life could adapt to these conditions, and any life in the exoplanet's potential oceans would be more protected.

Life on Earth is thought to have moved from oceans to land about 450 to 400 million years ago. This step might not be possible for planets around red dwarfs like Proxima Centauri due to the hostile surface environment maintained by flares, says Méndez. "If life is limited to the oceans, this might also exclude intelligent life capable of technology." For example, they wouldn't be able to make fire, he says.

When looking at wavelengths of light absorbed by molecules in the planet's atmosphere, methane and carbon dioxide might mask signs of water, making it potentially harder to detect signs of life, he says. ▮

ESO/M.KORNMESSER

The red dwarf Proxima Centauri blasts nearby planets with solar flares

Human evolution

When our ancestors started to run

Hominins may have begun running a million years before we thought

Colin Barras

THE ancient human species *Australopithecus afarensis* may have been the earliest hominin to run on two legs. Although it had relatively short, ape-like legs, *A. afarensis* may have had shared a musculoskeletal feature with modern humans that enables us to run efficiently.

Conventional thinking is that early hominins like *A. afarensis* – the species to which the famous Lucy fossil belonged – walked on two legs long before they could run. Lucy was an ape-like bipedal hominin seen by some as a likely direct ancestor of the earliest species of human.

Some evidence places the origin of bipedal walking more than 10 million years ago. But many researchers think it was only with the appearance of the human genus *Homo*, between 2 and 3 million years ago, that hominins began to run.

Ellison McNutt at the University of Southern California thinks the story is more complicated than that. Some earlier hominins should have had some ability to run when faced with a predator, for instance.

P. PLAILLY/E. DAYNES/SCIENCE PHOTO LIBRARY

Heel bones suggest that *Australopithecus afarensis* could have run if necessary

McNutt looked for evidence of running ability in *A. afarensis*, because this species appeared about 3.9 million years ago and disappeared a million years later, about the same time as the first humans, such as *Homo habilis,* evolved.

She and Jeremy DeSilva at Dartmouth College in New Hampshire focused on the Achilles' tendon, a band of tissue connecting the calf muscles to the heel.

Modern humans have a long Achilles' tendon that extends more than halfway up our lower leg. It stretches when we run to store elastic energy that it then releases explosively. This helps us to use 35 per cent less energy when running. "A long Achilles' tendon is helpful for efficient walking, but it is especially critical for efficient running," says McNutt.

Tendons rarely fossilise. But by studying the shape of the heel bone in humans and 11 other living primates, McNutt and DeSilva discovered that the size of one part on the rear of the heel bone scales with the length of the Achilles' tendon.

When they measured two *A. afarensis* heel bones, they calculated that the species might have had an Achilles' tendon that extended more than halfway up its calf, just as we do (*The Anatomical Record*, doi.org/dprh). For comparison, chimpanzees – which can't run well on two legs – have an Achilles' tendon that stretches barely higher than the ankle.

"Currently, I think *A. afarensis* is the earliest hominin for which we have good evidence for some of the key adaptions necessary for modern human-like running," says McNutt.

35%

The running efficiency gained due to the human Achilles' tendon

But we know there were earlier bipedal hominins, such as *Ardipithecus*. McNutt says as we learn more about these species, we might conclude that even earlier hominins were also born to run. ▮

Solar system

Comet 67P's hidden nitrogen may solve a solar system puzzle

COMETS appear to have 10 times less nitrogen than they ought to, based on our understanding of how they form, but a finding from comet 67P/Churyumov-Gerasimenko might reveal how they have been hiding this element.

The European Space Agency's Rosetta spacecraft orbited 67P between 2014 and 2016. Analysis of the light bouncing off the comet revealed that some compound was absorbing light from its surface, but researchers couldn't immediately identify this chemical.

Olivier Poch at the University of Grenoble Alpes in France and his colleagues compared the properties of that light with that of light bounced off artificial asteroid dust in the lab. This contained dust grains similar to those known to exist on 67P, as well as various other compounds. There was a close match with ammonium salts, which contain nitrogen and hydrogen (*Science*, doi.org/dprs). This could help explain where the missing nitrogen is.

The team found similar observations from asteroids, which means these rocks could also have such salts on their surfaces.

The discovery could also help explain how some of the solar system's giant planets formed: measuring how much nitrogen they have and comparing it with the amount in comets could reveal if comets made up young planetary cores, says Kathleen Mandt at Johns Hopkins University in Maryland.

"It could be valuable information for understanding how the ice giants formed and how many comets might be in there," she says. That would help us understand what proportion of the early planets were made of solids like comets and asteroids as opposed to gas.

"Nitrogen-rich comets could have made up planetary cores and may help explain how giant planets formed"

Ammonium salts are important to the chemical reactions that form the amino acids that living organisms are made from, as well as the building blocks of DNA, says Poch.

"There is a tantalising scenario in which you can imagine that if comets such as 67P fell on the early Earth and the ammonium salts dissolved in water, you may have had all these prebiotic reactions happen," he says. If that did occur, comets could have been important not only to the formation of planets, but also to the evolution of life. ▮

Leah Crane

NORTHERN SPAIN

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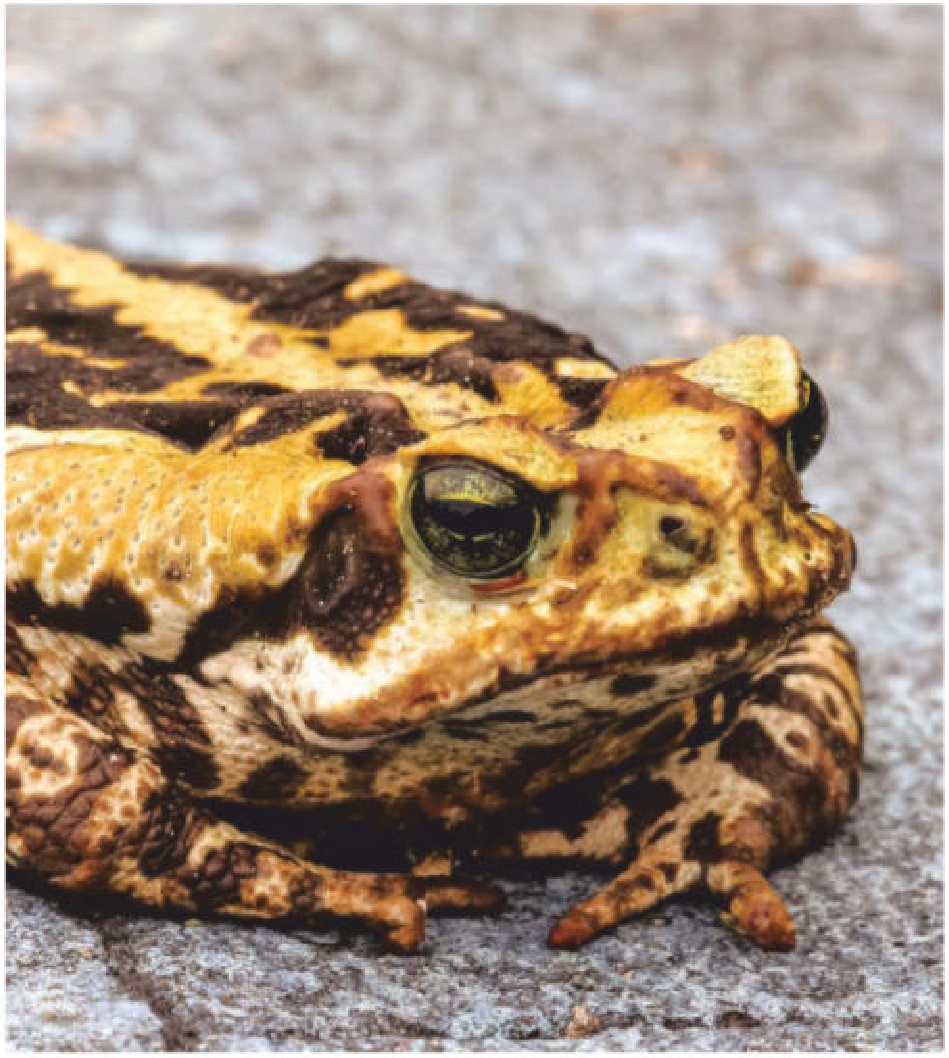
Animal behaviour

Toad eats live scorpions and survives toxic sting


UWE-BERGWITZ/ISTOCK/GETTY IMAGES PLUS

A SOUTH American toad gobbles up venomous scorpions – and is unfazed by a dose of venom equivalent to 10 stings from its prey.

Carlos Jared and his colleagues at the Butantan Institute in São Paulo, Brazil, studied yellow cururu toads (*Rhinella icterica*) as they feasted on yellow scorpions (*Tityus serrulatus*).

Both animals are common in Brazil, but until now only anecdotal observations suggested these toads (pictured) prey on scorpions.

Brazil sees around 156,000 scorpion sting cases annually, the main offender being the yellow scorpion, which can kill people. Shrinking habitats have forced the scorpions into cities where they lack predators and breed easily.

Meanwhile, the toads are often treated as "repugnant pests". Jared hopes they will now receive praise as natural scorpion-exterminators.

After placing toads in large plastic boxes with soil at the bottom, the researchers gave 10 of them two chances to catch and eat a yellow scorpion within 5 minutes. Seven toads ate both scorpions, two ate just one and one didn't catch any.

Videos showed that, before swallowing, a toad would swiftly load a scorpion into its mouth using its tongue, front legs and jaws. Analysis of the footage suggests the toads were stung inside the mouth, yet they remained unharmed.

To see if the scorpion's venom affects the toads, the researchers injected five of them with five times the dose that would kill a mouse – or the equivalent of 10 scorpion stings. All survived and seemed unshaken (*Toxicon*, doi.org/dpqn).

James Urquhart

Exoplanets

Cloudy, with a risk of liquid iron rain

AN exoplanet similar to Jupiter could have the ultimate bad weather: iron rain.

"It showcases probably one of the most extreme planetary climates we've ever seen," says David Ehrenreich at the University of Geneva in Switzerland.

The planet, called WASP-76b, is about 390 light years away from our solar system. It is a gas giant similar to Jupiter, but with a much shorter orbit around its star, taking fewer than two Earth days to circle it. The same side of the planet always faces its star, and because it is orbiting so close, the day side is about 1000°C hotter than the night side, reaching temperatures of about 2400°C.

This means the side facing towards Earth is too dark to be seen by telescope, but a small amount of starlight filters through the planet's atmosphere, revealing details about what is going on. The team analysed this light and detected a signal of gaseous iron, which is also found in the atmospheres of other ultra-hot Jupiters.

WASP-76b's gaseous iron signal, however, was unevenly distributed, depending on whether the atmosphere was moving from the planet's day to night side or from the night side to the day side.

Because the transition of the atmosphere from the hot to the cooler side of the planet results in a drastic temperature drop, the team thinks the gaseous iron condenses into clouds when it reaches the darker, colder side of this world, which could mean that it rains liquid iron droplets during WASP-76b's night (*Nature*, doi.org/dprk).

It seems likely that iron rain is present on this world, says David Armstrong at the University of Warwick, UK. **Gege Li**

Botany

Genetics of coffee crop put it at risk

DNA sequencing has confirmed that a lot of the coffee we drink is from one of the least genetically diverse crops in the world, making it more vulnerable to extinction.

Arabica beans (*Coffea arabica*), harvested from the berries of the plant (pictured), make up about 60 per cent of the world's coffee, but it is severely endangered by climate change, says Simone Scalabrin at IGA Technology Services in Italy.

NIGEL CATTLIN/ALAMY

We already knew the Arabica genome is the result of the fusion of two species, *Coffea canephora* and *Coffea eugenioides*, but we didn't know if today's Arabica is from this event occurring several times, or just once. To find out, Scalabrin and his colleagues used whole genome sequencing on 736 samples of Arabica plants.

They found that the genetics of the samples were more than 99.9 per cent similar. This low genetic diversity suggests these plants are the result of a single random hybridisation event.

While the event may have occurred more than once, this analysis suggests only one of these lineages survived, which means that every Arabica plant today has a common ancestor that is around 10,000 to 20,000 years old (*Nature Scientific Reports*, doi.org/dpqq).

"It is one of the least genetically diverse plants in the world," says Scalabrin, making it vulnerable to climate change, pests and disease. **Jason Arunn Murugesu**

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Really brief

ZEPHYR/SCIENCE PHOTO LIBRARY

Strokes now less deadly in London

Rates of death and disability caused by stroke have dropped by nearly a quarter in the past 16 years in south London. The change is probably due to faster hospital treatment and better longer-term care and rehabilitation (*PLoS Medicine*, doi.org/dpqs).

Fish favour small robot guardians

Salmon seem to prefer small robots to larger ones, which could help guide how we automate fish farms. In a test with a human diver, a large robot and a small robot, farmed salmon beat their tails slower near the latter, which suggests they found it less disruptive (*Royal Society Open Science*, doi.org/dpqt).

Mars mission gets put back two years

The European Space Agency and Russia's Roscosmos agency have delayed a planned robotic mission to Mars. The second ExoMars mission was due to launch in July or August this year, but is now on hold to 2022. Technical issues are mostly to blame, but the coronavirus outbreak hasn't helped, the agencies have said.

Microbiology

Why bacteria make the ultimate sacrifice

WE KNOW some bacteria self-destruct when their colony is attacked by other microbes, but the reason was unclear. Now it seems they sacrifice themselves to save their relatives.

This is rare in nature because it usually contradicts an individual's evolutionary drive to survive and reproduce. However, many types of bacteria do self-destruct when attacked by rival bacteria.

To try to understand why, Elisa Granato and Kevin Foster at the University of Oxford developed a way to visualise this. They took a strain of *E. coli* that can self-destruct in the presence of a competitor's toxins and made the strain turn green when it is preparing to self-destruct and pink when it actually does so.

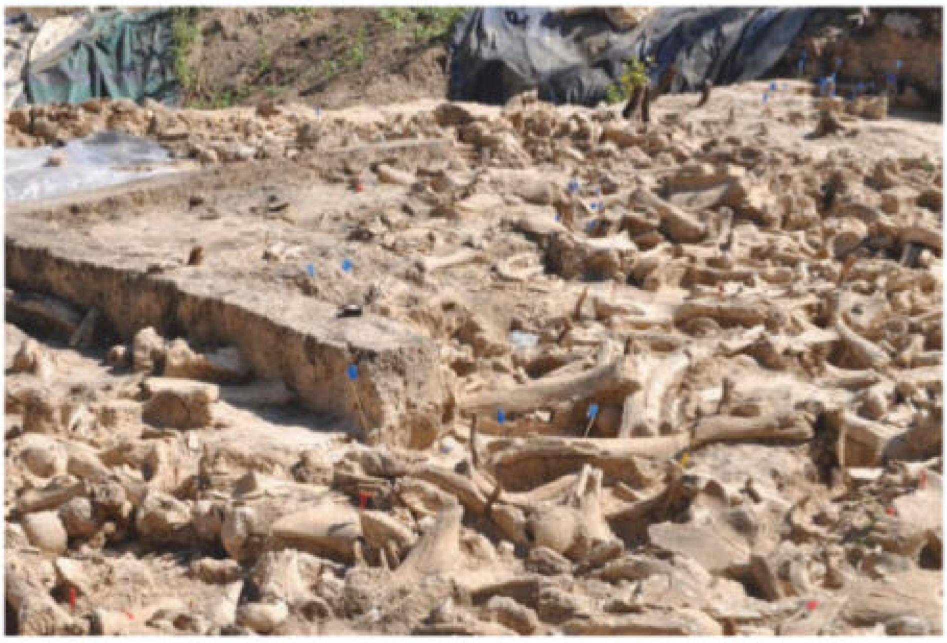
The researchers placed a colony of the modified bacteria in a dish next to enemy bacteria – a different, unmodified strain of *E. coli* – and watched them.

The modified *E. coli* on the front line, closest to the enemy bacteria, received a direct hit of the toxins released by their rivals and were killed straight away. Soon after, the *E. coli* just behind the front line, which were exposed to less toxin, switched into self-destruct mode.

These bacteria spent an hour building up their own toxin, before bursting open and firing the toxin at the enemy, probably to help the rest of the colony survive (bioRxiv, doi.org/dprb).

This makes evolutionary sense, as bacteria often live in colonies of identical clones, says Granato. "It's like they're helping their own genes by killing themselves," she says. **Alice Klein**

Archaeology


A J E PRYOR

Ancient 'bonehenge' may have had ritual significance

A PREHISTORIC circle made almost entirely of mammoth bones that was unearthed in Russia has been analysed for clues to its purpose.

During the latter part of the Stone Age, many bone circles were made in eastern Europe and northern Asia. One of the best-known sites is Kostenki 11, south of Voronezh in Russia. Two bone circles were found there in 1951 and 1970.

Then in 2014, a third was found (pictured). Now Alex Pryor at the University of Exeter in the UK and his colleagues have investigated it.

The circle is about 12.5 metres across. Mammoth bones have been piled up to form a wall 1 to 2 metres thick and possibly 50 centimetres high, with no obvious entrance. It is about 20,000 years old, according to studies that dated the bones.

Bone circles at other sites have been interpreted as dwellings. However, Pryor says that is unlikely in this case. The internal space is so large, it would be difficult to build a roof with prehistoric materials.

It may have been used for processing food – perhaps tuber vegetables, similar to parsnips, that could survive in the frigid climate. Alternatively, the bone circle could have had a ritual significance (*Antiquity*, DOI: 10.15184/aqy.2020.7). **Michael Marshall**

Genetics

Half of US would sell their gene data

A SURVEY of people in the US has found that 50 per cent would hand over their genetic data for $95.

Forrest Briscoe at Pennsylvania State University and his colleagues asked more than 2000 people, a representative sample of the US population, about the use of their genetic data. They watched a 3-minute video detailing both the commercial value of genomic data and privacy issues. This included a statement that when consumer genetic data has been sold to pharmaceutical firms it fetches around $130 per individual's data.

The participants were split into five groups and asked if they would grant access to their data – for free or for money – to one of five types of body: a non-profit hospital, a pharmaceutical firm, a tech firm, a university research lab and a US federal research agency.

While 38 per cent said they wouldn't share data, 50 per cent said they would if paid and 12 per cent would do it for free. Those who wanted to be paid expected a median of $130, but would accept $95 if they also received a health and ancestry report based on their genetic data. The team found the type of organisation getting the data made no difference (*PLoS One*, doi.org/dprd). **JAM**

Genetic modification

A French food fight

The highest court in France has ruled that many common crops are illegal. Enforcing the law will be near impossible, reports **Michael Le Page**

OVERSNAP/GETTY IMAGES

Many French-grown sunflowers have new genetic traits

CROPS that have been grown and eaten in France for years may soon become illegal. Farmers will no longer be able to plant them and shops won't be able to sell them.

At least, that is what is supposed to happen later this year. But because it will be virtually impossible to know which varieties are forbidden, it is far from clear how things will pan out.

"I think it's going to have a real impact on agriculture and plant breeding in France," says plant biologist Johnathan Napier at Rothamsted Research, UK. It will affect others, too, as France is the largest seed exporter in the world.

This extraordinary state of affairs stems from a 7 February decision by France's top court, the Council of State. It ruled that plants created by mutagenesis – the process of inducing genetic mutations – should be subject to the same European Union laws that cover genetically modified organisms (GMOs).

Although these gene tweaks might sound similar, they have conventionally been seen as quite different. Organisms constantly mutate because of mistakes that happen when DNA replicates as new cells are made or when it is damaged. Genetic varieties also develop when species interbreed, producing hybrid offspring.

By selecting mutant and hybrid plants with desirable properties, early farmers transformed wild species into the domesticated varieties that we eat today. Modern bananas are a long way removed from their wild relatives genetically, for instance.

From the 1950s, breeders began to intervene more. They exposed seeds to radiation or toxic chemicals to induce mutations by chance, hoping to get lucky with desirable traits. This process, called random mutagenesis, has been used to create thousands of plant varieties grown today, including many wheat and rice strains.

In the 1980s, breeders went a step further. They started creating plants with properties such as herbicide resistance by adding new genes. Because these genes often came from different organisms such as bacteria, these GM crops were seen as being different from those produced by mutagenesis.

"Early farmers grew mutants, transforming plants into the varieties we eat today"

Public concern about the safety of such GMOs led to many countries introducing laws to regulate them. In 2001, an EU directive defined GMOs as those "in which the genetic material has been altered in a way that does not occur naturally".

Under this directive, genetically modified plants have to undergo stricter testing than other new plant varieties before they are approved, and most products made from them must be labelled.

Meanwhile, plant breeders were developing techniques that blur the line between random mutagenesis and adding new genes. For instance, if you know which gene needs to be altered, you can mutate plant tissues growing in a dish, sequence thousands of cells to find those with the right mutation and use them to grow plants. It is laborious, but quicker than waiting for thousands of plants to grow.

Using new breeding techniques, companies began to create crops with the same traits as GM ones, such as herbicide resistance, but which weren't subject to GM regulations. By area, about a third of the sunflowers grown in France are herbicide resistant, for instance.

In 2015, eight anti-GM organisations in France, including the Peasant Confederation – farmers who favour traditional methods – called for the government to ban these herbicide-resistant crops. When it refused, they appealed to the French Council of State, claiming that these crops should count as GM under EU law.

The case was referred to the European Court of Justice, which in 2018 ruled that all organisms obtained by mutagenesis should indeed be regulated as GMOs under the 2001 directive. The court said the directive clearly excluded the methods of random mutagenesis used since the 1950s, but that member states were still "free to subject such organisms" to the directive's regulations.

This had no immediate consequences, because it is up to member states to apply the ruling. But in February, the Council of State ordered the French government to withdraw approval for certain varieties.

"The French government is legally bound to implement the decision of the Council of State," says Guy Kastler, a founding member of the Peasant Confederation.

Which varieties will be withdrawn is still far from clear. The French ministry of agriculture didn't respond to *New Scientist*.

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In fact, it isn't answering anyone's questions.

"We have raised a lot of questions with the government," says Emmanuel Lesprit from the French Seed Union, which represents seed companies and plant breeders. "We have no answers."

A variety of opinions

Kastler says the decision applies to "random mutagenesis in vitro", that is, mutating cells rather than working "in vivo" on whole plants, and the only examples he knows of are herbicide-resistant crops.

Petra Jorasch of Euroseeds in Brussels, a non-profit organisation representing people who grow and sell seeds in Europe, disagrees. She doesn't think the ruling applies only to in vitro mutagenesis, and might not even be limited to varieties introduced after 2001. In any case, she says, there is no clear dividing line between in vivo and in vitro mutagenesis.

Martin Wasmer at the Centre for Ethics and Law in the Life Sciences in Hannover, Germany, says even the in vitro definition encompasses at least several hundred varieties, and would apply to ornamental plants as well as those grown for food.

In theory it would not only be illegal for farmers to grow withdrawn varieties, it would also be illegal for products made from them to be sold in France, even if they are grown elsewhere in the EU or outside the EU. It isn't clear if France can or will attempt to enforce this.

Implementing the ruling means identifying which varieties were created by the methods in question. The trouble with this, says Jorasch, is the national and EU-wide catalogues of approved non-GM plant varieties don't record how those varieties were created.

French authorities would have to track down the breeders of each variety and ask them, she says. And the breeders might not even know, because they often use plants created by other groups as a starting point.

What's more, even if these varieties could be identified, there is no way for retailers in France to know if food they import from other countries derives from the varieties in question. And if shops in France stop selling some of these products, they will be breaching EU rules. "It would violate the treaties of the EU on the free movements of goods," says Wasmer.

The matter has been referred to France's High Council for Biotechnology, an independent body which has to advise the French government by August. The government then has until November to implement the decision.

There is also confusion over what happens if plant varieties first approved in France are removed from its national catalogue. Non-GM plants approved in one member state are automatically added to the EU's common catalogue. If France withdraws varieties it approved, it isn't clear if other member states can keep growing them.

Boulangeries may have to stop selling bread made from some wheat strains

PIERE BONBON/ALAMY

One way to resolve this issue would be to change the 2001 GMO directive, which many researchers have already recommended should happen. In November 2019, for instance, European advisory committees on biosafety wrote to the European Commission saying that there is usually no way to tell from the DNA sequence of an organism whether it has been created by natural mutations, mutagenesis or gene editing.

8

Number of anti-GM groups that triggered a court ruling in France

They want the regulatory regime to focus on the effect of any genetic modifications rather than on the method used to make those modifications.

But Wasmer thinks it will take at least five years to change the directive if it does happen. In the meantime, he expects anti-GM organisations in other EU countries to bring similar cases to the courts, meaning more countries could soon face the same conundrum as France.

The UK probably won't be one of them – Brexit means it is likely to diverge from EU legislation. "There's an opportunity for the UK to do something different," says Napier. "But the country will have to tread carefully because of the issues around trade." ▮

Working hypothesis

Sorting the week's supernovae from the absolute zeros

▲ Minor planets

Astronomers have discovered 139 more trans-Neptunian objects, or minor planets, making Pluto even less special.

▲ Right to repair

Screen smashers rejoice! The European Commission is planning legislation to make it easier to get your phone fixed.

▼ Polar ice caps

Coronavirus isn't the only thing to worry about. The polar ice caps are melting nearly six times faster than in the 1990s.

▼ Big telescopes

A 10-year survey by the Vera C. Rubin Observatory in Chile may have to run for an extra four years due to predictions that SpaceX's Starlink satellites will spoil 30 per cent of its images.

▼ Dead Sea Scrolls

Supposed fragments of the Dead Sea Scrolls held at the Museum of the Bible in Washington DC are fakes, possibly made from old shoe leather.

BOTTOM: BIBLELANDPICTURES/ALAMY; TOP: NASA

THE TRUTH ABOUT EQUALITY IN STEM

What form does discrimination take in science careers, and how prevalent is it? The STEM Survey 2020 lifts the lid on prejudice in the workplace

NEARLY 29 per cent of those working in science and technology careers have experienced discrimination of some kind at work, according to this year's STEM Survey. This is higher than the average figure for UK workers, but may indicate that people working in science are getting better at recognising and calling out discrimination.

The STEM Survey 2020, conducted by *New Scientist* in association with recruiter SRG, takes a look at the science job market. It brings to light some positive news: that careers in science are long and fulfilling despite the turbulent economic times. But it also examines the challenges STEM workers face, including workplace discrimination.

The survey reached nearly 3000 people employed in STEM, mostly in the UK plus a small number in other countries. As well as asking them what sorts of discrimination they had encountered, it also gave people the chance to write about their experiences.

Discrimination is the prejudicial treatment of different categories of people. It is against the law in the UK to discriminate on the basis of a person's age, sex, gender, race and other protected characteristics.

Surveys tend to suggest that about a quarter of all workers in the UK have experienced some form of discrimination, which is in line with last year's STEM Survey. It might seem bad that the figure has come out higher in this year's survey, but there is a caveat. As the 2020 survey asked respondents about their whole careers, the incidents they reported didn't necessarily take place within the past year. The increased figure could therefore reflect a growing awareness of what constitutes discrimination and a greater confidence in reporting it.

35%

Percentage of women working in STEM who say they have experienced discrimination

This sentiment was echoed by participants that *New Scientist* spoke to in more detail. One young scientist in the UK said: "I don't think that the actual incidents have increased. I think it has become clearer what is acceptable and what is not. And because of #MeTooSTEM and other movements, the people who have been affected find it easier to speak out and seek appropriate support."

Perspectives differed a little in North America, where one postdoc said: "Since movements like #MeTooSTEM, people are more aware, but in my experience, this leads to more jokes about being 'extra sensitive'."

When respondents were asked about the type of incidents they had faced, gender-based discrimination came up most often (see "On what grounds?", right). In fact, women were more likely than men to experience discrimination of any kind: 35 per cent of the women surveyed said they had, compared with 22 per cent of men.

Of the men who felt that gender had played a role in discrimination they faced, many talked about their experiences after having children. One academic from Switzerland said: "For me, it all started when I became a father and therefore I was unable to keep working the same amount of hours in excess of our business hours. From then on, I was told that I had made the choice myself of NOT advancing my career."

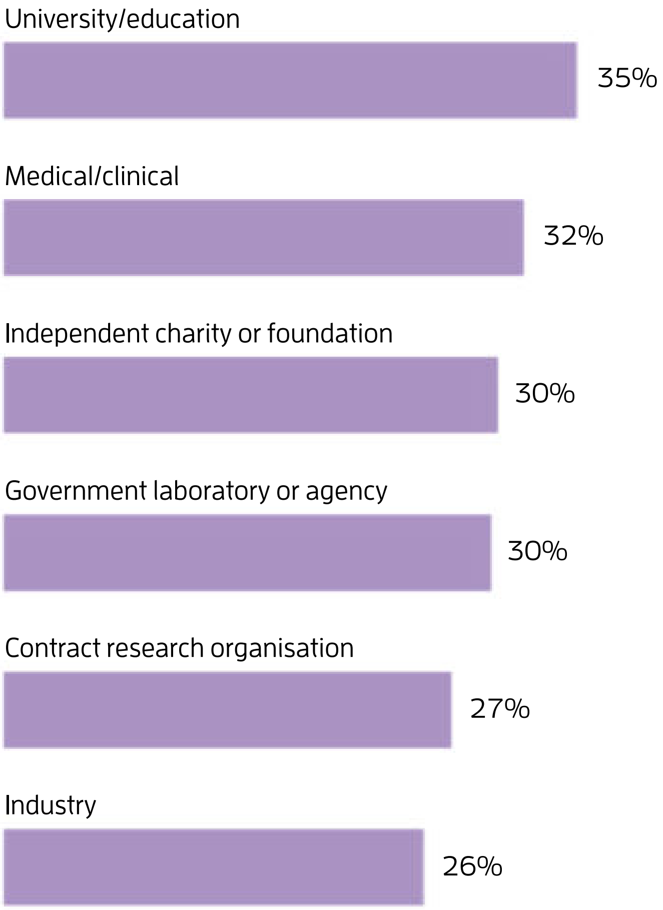
Part-time workers were also more likely to face discrimination, especially on the basis of gender. This might partly account for the 20 per cent gender pay gap that the survey also identified. About 9 per cent of women were working part-time versus 3 per cent of men. Women are more likely in general to reduce their working hours due to family commitments.

With most of our respondents based in the UK, it was possible to build a picture of which parts of the country experience the most discrimination. The areas with the highest incidence were Northern Ireland and Yorkshire. Different areas also had different profiles in terms of the kinds of discrimination experienced there. In Northern Ireland, for example, a large proportion of discrimination was based on sexuality. Until January 2020,

SEB OLIVER/CULTURA/SCIENCE PHOTO LIBRARY

SECTOR DIFFERENCES

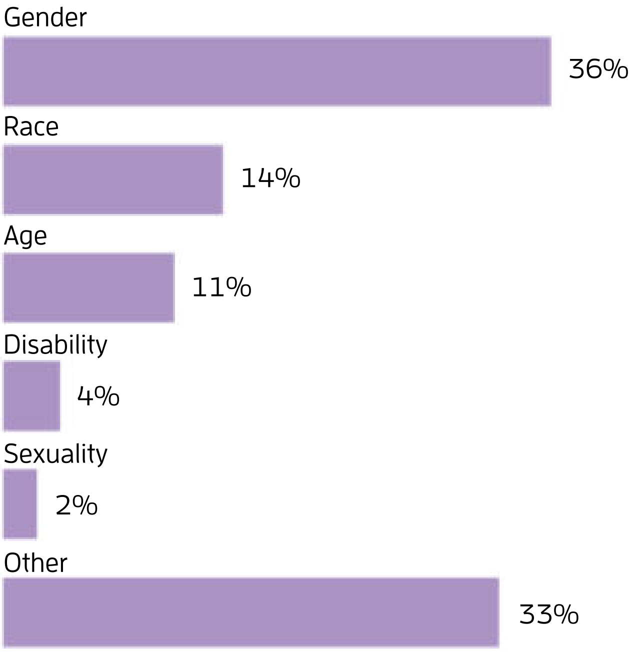
The percentage of respondents that had experienced discrimination in different employment sectors



UK respondents (rounded to nearest whole number)
SOURCE: NEW SCIENTIST/SRG/2020 SALARY SURVEY

ON WHAT GROUNDS?

We asked those respondents who had experienced discrimination the principal characteristic for which they had been unfairly treated



UK respondents (rounded to the nearest whole percentage)
SOURCE: NEW SCIENTIST/SRG/2020 SALARY SURVEY

same-sex marriage was banned in Northern Ireland, whereas it was legalised in Great Britain more than five years ago. The survey also revealed which employment sectors appear to have the most discrimination (see "Sector differences", above).

When it comes to company size, you might think that when there are more employees, it is easier to get away with bad behaviour. That isn't necessarily so. One manager in a small medical devices firm told us: "I realised that there are no or not enough checks to prevent any kind of discrimination. You just have to rely on the personality and moral compass of the individual and that is not enough." In fact, the survey found no sure correlation between company size and discrimination.

What about younger people? Only 17 per cent of 20 to 24-year-olds surveyed said they had experienced discrimination. In contrast, 43 per cent of 45 to 54-year-old respondents said they had. It is easy to assume this can be explained by age: older people have been working longer and have had more time to come across such situations. But the trend didn't hold with 55 to 64-year-olds, only 30 per cent of whom felt they had been discriminated against. It seems, then, that those people aged 45 to 54 are experiencing more discrimination than other age groups, for reasons that aren't clear.

Ultimately, however, it seems that discrimination isn't what the majority of people in STEM are most worried about. Whether or not they had experienced discrimination, it didn't significantly affect their priorities when moving jobs. For both those who had and those who hadn't, an increase in pay and interesting work were their top proirities.

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Coronavirus

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We must also plan for the possibility, however unlikely, that in the next few weeks we may not be able to get a magazine published and delivered to both newsstands and subscribers because of some unforeseen circumstances.

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All the best,

Emily Wilson Editor, *New Scientist*

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Comment

In defence of organic food

Claims that organic farming is worse for the environment are too simplistic, say **Christel Cederberg** and **Hayo van der Werf**

JOSIE FORD

PEOPLE are keener than ever to make ethical, environmentally friendly food purchases. But a spate of bad press about the environmental impact of organic produce may leave some people scratching their heads.

The debate about this is contentious. Critics say organic farming is less efficient than conventional farming, and so uses more land, leading to greater deforestation, which causes higher carbon dioxide emissions and biodiversity loss. A recent paper followed this logic to find that going 100 per cent organic in England and Wales would raise these emissions by up to 56 per cent. The claim made headlines .

But the findings from this study and similar ones are too simplistic and ignore important positive aspects of organic farming. We have analysed such studies and found that the method they often use doesn't give the full picture.

Known as a life cycle assessment (LCA), this approach simply relates environmental impacts to the amount of product harvested from a given area of land. Looked at this way, intensive farming is often more efficient, since its yields are higher. But this doesn't properly address all environmental aspects.

Such assessments fail to fully account for the role of land degradation, biodiversity decline and pesticide impacts of intensive agriculture.

Consider biodiversity, for example. The variety of life on Earth is an incredibly important factor in the health and resilience of ecosystems. But worldwide, it is in decline – insect and bird populations are being decimated, something that has been repeatedly linked to the damaging practices of intensive farming. Organically managed land, however, has been shown to support biodiversity levels around 30 per cent higher than conventionally farmed fields.

It might be argued that the land saved through conventional farming could be reserved for biodiversity and CO_2 absorption. But the relationship between agricultural intensification and reduced deforestation is unclear. In Brazil, for example, agricultural intensification has coincided with more deforestation.

Widespread use of pesticides is also a concern – between 1990 and 2015, global pesticide use has increased more than 70 per cent. Pesticide residues can be harmful to land and aquatic ecosystems, as well as our health. The avoidance of synthetic pesticides in organic farming, and the overall much lower levels of pesticide use in general, is a factor that is often overlooked in LCAs. In the 34 studies comparing organic with conventional agriculture that we reviewed, only nine looked at pesticide-related impacts.

The debate around the environmental impact of organic farming has become too simplistic and narrow. Our review, published in *Nature Sustainability*, shows that organic farming's strengths and environmental benefits are often overlooked by the current research, and simply claiming that organic farming is worse for the environment is misleading.

The current use of LCAs needs to be improved and integrated with other environmental assessment tools. Only then will consumers get a more balanced picture. ▮

Christel Cederberg is at Chalmers University of Technology, Sweden, and Hayo van der Werf is at INRAE, France

James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, he shares his tiny London flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

James's week

What I'm watching

Swamp Thing on Netflix*. Embarrassing, I know. But, seriously, its hero is part-human, part-botanist. Can you blame me?*

What I'm reading

Mountains of academic journals, as per usual.

What I'm working on

A new TV series and podcast, both about plant science. Having a great time.

This column appears monthly. Up next week: Chanda Prescod-Weinstein

#FactsMatter

Is your salad going to kill you?

Plants need nitrates for good growth, but they can also accumulate in leaves of crops like rocket. So are foods like this safe to eat, wonders **James Wong**

EATING healthily can be tricky, especially for avid followers of the latest food-related headlines. Even fare touted as a superfood one day can be vilified as a cancer risk the next. Perhaps nowhere is this more the case than in recent claims about rocket, a salad leaf.

It is "at the centre of cancer concerns", said one story, a strong accusation to level at a humble leaf. The claim hinges on high levels of nitrates that rocket contains. Is there any clear evidence to back it up? No, not when you dig a bit deeper into the complex findings around this.

Nitrates are naturally occurring mineral compounds that plants need for healthy growth. These are drawn up from the soil and become concentrated in the leaves in some species. It has long been known that rocket is a particularly potent accumulator of these substances. So what is the issue?

Well, from the late 20th century, we started becoming concerned that nitrates might pose a health hazard. This was largely about their presence in drinking water as a consequence of fertiliser that washes off farmland and their use as food additives, for example to preserve processed meats. Those worries were sparked by experiments that involved feeding large quantities of nitrates to rats, which suggested a raised risk of conditions such as stomach cancer.

Based on these findings, legislation was brought in decades ago by the likes of the World Health Organization and the European Union to limit nitrates in food to what were considered safe levels. Given nitrates are in rocket, the rules applied to it too.

How strong was the evidence on nitrates though? It is important to remember that, in science, not all evidence is created equal. The results of animal studies are often a poor guide to what will happen in people. Furthermore, feeding lab rats heavily nitrate-laced water isn't exactly a great proxy for our salad consumption. Studies that look for a relationship between real-world behaviours in people (such as tracking actual nitrate consumption) and health are generally considered far better evidence. So what do these show?

One of the most comprehensive reviews of this type of evidence, conducted by China's Fudan University, reported no clear positive association between overall cancer risk and nitrate intake. In fact, in the case of gastrointestinal cancer a slightly lower risk was observed, particularly in the group whose consumption was the highest.

> "It is important to remember that, in science, not all evidence is created equal"

When it comes to looking for links between intake of nitrate-rich vegetables, such as rocket, beets and spinach, and broader health outcomes, results are encouraging. For example, the University of Plymouth, UK, reported that vegetarians, who can consume three times the average amount of dietary nitrate, tend to have a lower cardiovascular disease risk.

What's more, since the original cancer-link research in rats, many human trials in the past decade have shown dietary nitrate in the form of vegetables can have significant health benefits, including reduced blood pressure, which is statistically associated with a far lower risk of dying from cardiovascular disease, and even improved athletic performance. This has led some researchers to now go as far as to suggest that the naturally occurring dietary nitrate from vegetables "should be considered as a nutrient necessary for health, rather than as a contaminant". That's fighting talk.

So does all this mean that public health officials who moved to limit nitrate intake in the past got it wrong? Not necessarily.

While the new evidence of potential health benefits of dietary nitrate is intriguing, it isn't an effect that has been shown universally across all trials and most of these studies are relatively short term, so we lack data for the long-term effects. It is perfectly possible that the same compounds at low levels may be beneficial, but harmful at high ones. Indeed, if dietary nitrate is one day considered a nutrient, this would hardly be surprising, as many nutrients, such as vitamin A, are also toxins in too high a dose.

In all the relevant studies used for setting nitrate limits, the authors went to great lengths to point out the limitations of their data, as well as highlighting that the benefits of eating fruits and vegetables far outweigh any downsides of their nitrate content.

One more point: the existing limits on nitrate in foods aren't meant to warn consumers off eating crops like rocket, as some headlines imply, but are more a guide to farmers to signal when they should change practices to help reduce nitrate levels.

The bottom line of all this? Eat your veg. Following standard dietary advice to aim for diversity will avoid the risk of having too much of one type of fruit or veg. There is so much more we need to uncover about nitrates, but for now, we can say your salad isn't going to kill you. ▮

NORTHERN SPAIN

Ancient caves, human origins

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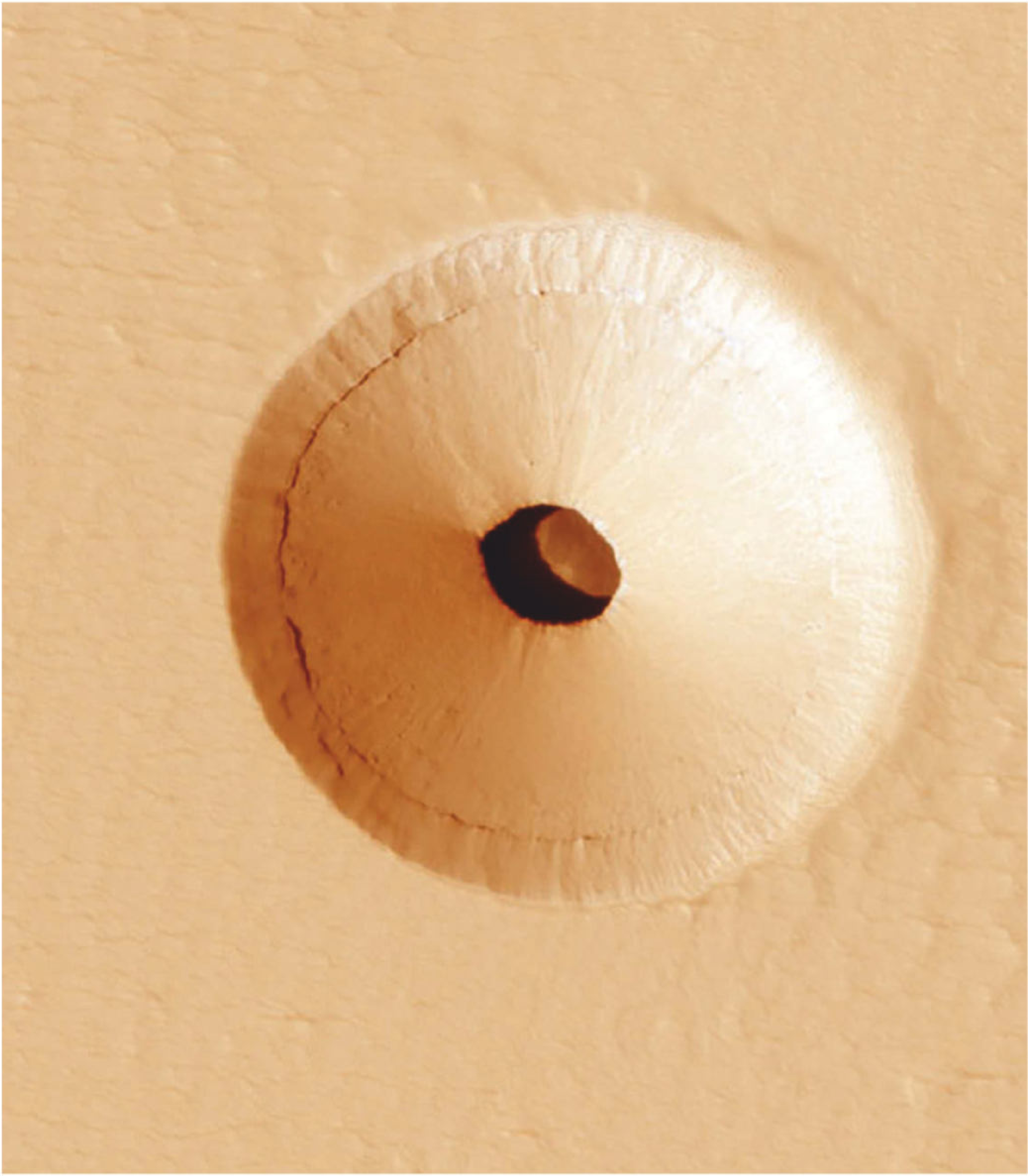


Martian mystery

Photograph **Mars Reconnaissance Orbiter**
Agency **NASA**

RAVAGED by the largest dust storms in the solar system and with temperatures that can fall to around -125°C, the surface of Mars is a hostile place. But what about beneath the ground – what might lurk there?

This image of an unusual crater on the slopes of Mars's Pavonis Mons volcano was captured in 2011 by the Mars Reconnaissance Orbiter, which is still surveying the Red Planet. NASA has reposted the image on its blog to stimulate fresh discussion about the crater.

The 35-metre-wide hole at the centre of the crater opens to an underground cavern that is protected from extreme weather conditions, so may be more likely to have once housed life. It is thought to have been almost 90 metres deep before debris within the crater above fell in and filled some of the cavern. Now it is probably around 28 metres deep.

No one yet knows how the crater formed. It could have been created by past volcanic activity on Pavonis Mons, which, at more than 14,000 metres high, is nearly 1.5 times taller than Earth's Mount Everest. Lava that once flowed from the volcano hardened on the outside, while the lava below this continued to flow, forming structures called lava tubes, which could have resulted in the crater.

NASA says such caves are key targets for future exploration by robots and spacecraft – and perhaps even humans. ▮

Gege Li

Editor's pick

Flaws and a ray of hope in pandemic policy

29 February, p 7

From Colin Bargery, Ottery St Mary, Devon, UK

It seems very likely that, to slow the spread of covid-19, many people will be encouraged to self-isolate. This policy poses risks to local food banks and similar aid organisations. Hungry people may go to food banks and come into contact with others who could be in a poor state of health. At the time of writing, those on zero-hour contracts – whose employer has no obligation to provide minimum working hours – may have no money to buy necessities, even if they have a friend who can shop for them. They are well-represented among food-bank users.

A self-isolation policy assumes that people have both the financial and the social capital to survive for two weeks. Many visitors to the food bank with which I am involved have neither.

From Alan Bundy, Edinburgh, UK

The measures we are being encouraged to take to avoid covid-19 are equally effective against influenza. Will there be fewer cases of flu this year?

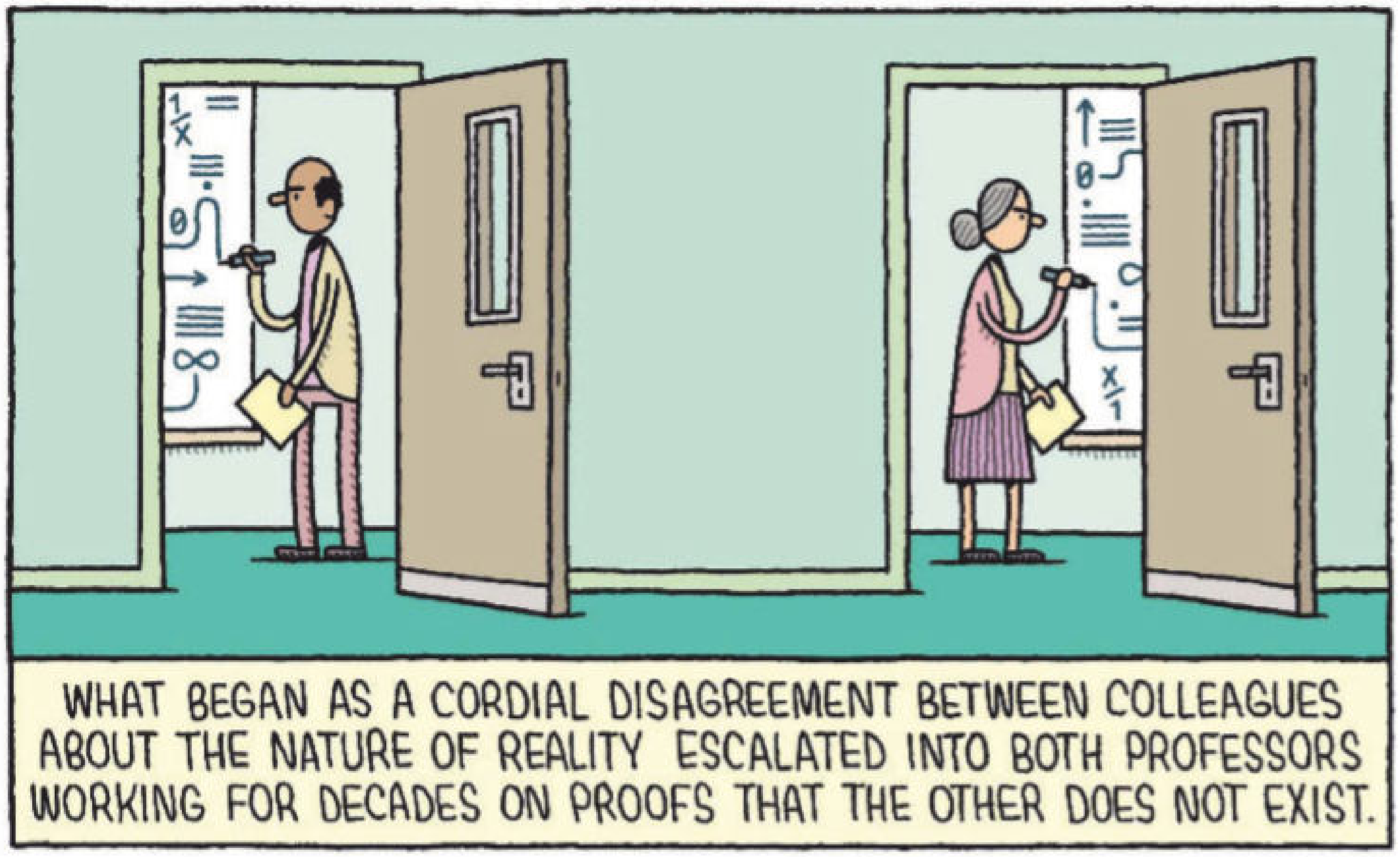
From Tim Joslin, London, UK

You report that, in some countries, many new covid-19 cases can't be traced to their source of infection. A test exists for the virus itself, but is it also possible to deploy one for antibodies to the virus?

Such a test would help detect transmission chains by revealing those who have recovered from covid-19. It would also allow its morbidity and mortality rates to be more accurately determined, simply by randomly sampling the population of an infected area.

The editor writes:

We have since reported online that many labs are trying to develop tests for the antibodies (6 March, newscienti.st/NS-tests).


WHAT BEGAN AS A CORDIAL DISAGREEMENT BETWEEN COLLEAGUES ABOUT THE NATURE OF REALITY ESCALATED INTO BOTH PROFESSORS WORKING FOR DECADES ON PROOFS THAT THE OTHER DOES NOT EXIST.

TOM GAULD for NEW SCIENTIST

We aren't smiling at this work on expressions

15 February, p 44

From Sam Edge, Ringwood, Hampshire, UK

Emma Young's article on facial expressions was very interesting. I was particularly taken with – though not surprised by – the implication that the FBI, other agencies and even commercial operations may be funding, and drawing conclusions from, questionable practices. These include programmes designed to train agents to spot signs of fear, stress and deception in people's faces and body movements.

Sadly, some law-enforcement agencies have form in this. Such organisations spend vast sums on polygraph "lie-detector" machines and on people who claim they can decipher their output objectively, despite the overwhelming evidence that false positives are common and false negatives are easy to induce (25 May 2019, p 18). They present probabilistic DNA and fingerprint evidence as incontrovertible fact, and so on.

I have no doubt that innocent people have been incarcerated – or in certain jurisdictions worse – as a result of legal professionals and juries taking this so-called expert testimony at face value, and that there are offenders at large because they were discounted using the same reasoning.

From Chris Tucker, Cambridge, UK

Young's discussion of facial expressions was fascinating, not least for reporting research where subjects were asked to match the "right" emotion to images of posed facial expressions. But how good were the posers?

I wonder, too, how our reading of facial expressions is affected by the phenomena of "selfie faces" and by what I call "TV-reaction faces" that people put on to display an expression as if they were characters in a soap opera.

The benefits of sorting stuff in alphabetical order

Letters, 29 February

From Kathy Nelson, Reading, Berkshire, UK

Why not change the order in which we teach the alphabet to the QWERTY keyboard layout, Linda Phillips asks. Well, not every language that uses the Latin alphabet uses that keyboard arrangement. As someone who touch-types, I frequently put spellcheckers to the test when visiting customers in France and Germany, where some keys aren't where my fingers expect them.

The sequence of the letters has never been relevant to learning to write by hand. Its utility doesn't disappear even if people mostly type. An agreed order is critical for sorting – allowing us to retrieve information efficiently. The ABC sequence is also useful because it maps onto other character sets, such as Greek and Cyrillic.

From Philip Belben, Nettlebridge, Somerset, UK

The principal benefit of traditional alphabetical order is felt in reference material. Although the corpus of reference texts available and searchable electronically grows ever larger, many of us find that the text we want isn't available, or is very expensive compared with a paper copy. In these cases, the index – and sometimes the body of the work – is arranged by the traditional alphabet, which anyone who wishes to find information in such a text must know.

We have to set net-zero carbon targets at scale

8 February, p 24

From Derek Bolton, Sydney, Australia

Graham Lawton draws attention to some of the subtleties of meeting targets for net-zero carbon emissions. Another arises when a relatively small area – that of a district council, say – sets such a goal. Too often, this means exporting surplus solar electricity during the day to offset usage at night. If many neighbouring areas do that, it doesn't scale: there is no one nearby to export to.

Scooters should announce their approach to be safe

29 February, p 25

From Ann Wills, London, UK

Donna Lu concludes that though e-scooters are a disaster for cities, we must embrace them as a lesser evil than cars. I suggest they should be manufactured to emit a sound, such as a buzzing or whistling noise, when moving, so pedestrians know there is one coming up behind them.

Their quietness is so dangerous. People who move unexpectedly on the pavement to look in a shop window and forget to look behind them first could be injured.

Let the people map out their own footpaths

Letters, 22 February

From Frank Bover, Thornbury, Gloucestershire, UK

Readers' comments on highway design made me think of one of my little "soap box moments". I have seen many grassed areas across which architects have laid attractive-looking walkways, only for the public to ignore these and take more expedient routes across the grass, creating muddy tracks.

Would it not be better to simply grass the whole area, wait for people to decide which way to cross it and then lay down paths along those routes? These may not look the most attractive on paper, but they would be more efficient.

Other university students with almost no brain

15 February, p 10

From Adam Ben-Dawood, Leeds, UK

Jessica Hamzelou reports on a bright teenager with half a brain who plans to go to university. The late John Lorber, professor of paediatrics at the University of Sheffield, reported several more extreme cases.

The most striking was that of a young man whose hydrocephalus apparently meant that he was missing almost his entire brain – yet he was studying mathematics at university.

Better bricks from bacteria must still breach barriers

25 January, p 18

From Fred White, Nottingham, UK

Your report on living concrete made with bacteria suggests a product that is comparable to a mortar mix. The BioMason group claims to produce blocks at ambient temperatures, using desert sand as aggregate, with strengths at least equal to industry standard lightweight blocks.

Sadly, vital technologies such as these must first overcome the inertia of established concrete-devouring industries and of risk-averse people who specify construction materials.

Perfectly free choice could only be the throw of a die

15 February, p 34

From Luce Gilmore, Cambridge, UK

Richard Webb notes a connection between "agency" and thorny concepts like free will. The problem of free will vanishes once it is accepted to be illusory.

Webb details his decision not to adopt a puppy, listing internal, external and historical considerations that influenced it. This is always the way: agency is contingent. Choices may be good or bad, but a perfectly free choice could only be random.

It would be like binding oneself to the outcome of a dice-throw, as in that dreadful old hound *The Dice Man* by Luke Rhinehart, in which a psychoanalyst stakes everything on the throw of a die.

I want us to curb the internet of everything

8 February, p 14

From Hugh Cooke, Lincoln, UK

A group of astronomers has called for legal action to stop the launch of vast numbers of satellites. They aren't the only people who should be concerned. Thousands of low-orbit satellites are being launched annually to provide universal secure internet services.

But the carbon emissions of the rockets used to launch them, plus the energy required to run the "internet of everything", guide our driverless transport systems and so on, will increase greenhouse emissions. It has been reported that on-demand video alone could produce a substantial proportion of global greenhouse emissions by 2025. Will the world at large voluntarily reduce its dependence on such technology?

I sometimes play hide-and-seek with curious spiders

8 February, p 42

From David Lee, Wellington, New Zealand

You report on spiders' intelligence extending beyond their bodies. I have often wondered about this when watching orb-web spiders spinning their webs: they seem to use a leg to "measure" the distance between strands.

I sometimes play hide-and-seek with black-headed jumping spiders – perhaps I have too much free time on my hands. I move my pointed finger slowly towards one until it backs away. Then I move my finger away, and the spider follows and touches it, showing what seems to me to be curiosity.

Can we be sure that burial was by Neanderthals?

29 February, p 19

From Karen Hinchley, Newark-on-Trent, Nottinghamshire, UK

Michael Marshall reports that evidence at Shanidar cave in Iraq suggests a Neanderthal corpse, known as Shanidar 4, was buried in a grave. Can we rule out that the burial was conducted by a human, given that archaeologist Emma Pomeroy, who was part of the team behind the discovery, says humans were displaying such behaviour at the time?

Let's not use these below-average earnings figures

29 February, p 22

From Dave Holtum, Bathampton, Somerset, UK

Why do you use mean salary in your annual survey of science earnings? Most employees will probably earn less than this average figure.

In 2019, the median income for full-time workers in the UK was £30,353 and mean earnings were £37,428 per year. A relatively small number of high earners skews these figures.

The median is the preferred measure: 50 per cent of salaries are less than it. In the UK, about two-thirds of full-time salaries are less than the mean. ▮

For the record

▮ There was some understanding of silver's antibacterial action before work on flagella revealed a new mechanism (7 March, p 15).

Want to get in touch?

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Marie Curie's luminous legacy

How do you reimagine someone as famous as the Polish physicist and chemist? Build a big picture of her work – and its future fallout, says **Donna Lu**

Film

Radioactive

Marjane Satrapi

UK cinemas, opens in US on 24 April

THE seriously famous always pose a problem for anyone wanting to re-explore their life and legacy. What is there left to say that someone hasn't said before?

For science, with so few global celebrities, Marie Curie is one of the hard cases. She is known as the pioneer of radioactivity, the first woman to win a Nobel prize – and the first person to win two.

That was the challenge facing director Marjane Satrapi when she first thought about making a biopic of the Polish physicist and chemist. Curie was one of Satrapi's two heroes while she was growing up in Iran around the time of the Iranian Revolution; the other was French writer Simone de Beauvoir.

Satrapi decided to base her film on the visual biography *Radioactive, Marie and Pierre Curie: A tale of love and fallout* by Lauren Redniss, which was adapted by screenwriter Jack Thorne. Drawing on the feel of the graphic biography and building a big picture of the implications of the Curies' work gave Satrapi ideas she hoped would resonate today.

The film illustrates what Marie Curie described as the "spontaneous luminosity" of radium, with a print tinged with a fluorescent palette. Paris, where much of the movie is set, is bathed in a foggy, greenish glow.

With Rosamund Pike in the lead role, the film spans more than a century, from the 1870s to the 1980s. It opens at the end of Curie's life, before flashing back to her younger days, starting with her first meeting (as Maria Skłodowska) with Pierre Curie (played by Sam Riley) in 1894.

Marie Curie was the first woman to gain a physics degree from the University of Paris. From the beginning, she was obsessive about her work. A female physicist in a field that was – and still is – dominated by men, her success was the result of that obsession and tireless work. "She's an uncompromising character," says Satrapi. "She's not a perfect spouse and she's not a perfect mother."

This is spelled out quite literally with shots of her asleep in the lab and in defiant interviews with all-male academic panels. Pike gives the character a clipped, matter-of-fact way of speaking, but her performance is hampered by clunky, obvious dialogue. "I refuse to be grateful," she says to Pierre Curie, when he invites her to work in his lab after a series of rejections by other scientists. In later scenes, she says: "I have been selfish my entire life," and "I just want to do good science."

The couple married in 1895, and the film takes us through the research that would lead to their joint 1903 Nobel prize in physics.

Marie Curie was the first person to win two Nobel prizes

HENRI MANUEL (DIED 1947)/PUBLIC DOMAIN

Building on the work of Henri Becquerel, who had discovered that uranium salts gave off invisible rays in 1896, Marie Curie was interested in pitchblende, a mineral rich in uranium. She noticed it emitted much more of what she later termed radioactivity than uranium alone.

Radioactive is cleverly shot. It shows the unglamorous reality of aspects of science, such as grinding down tonnes of pitchblende to isolate its components, a process that led the couple to discover the elements polonium and radium.

The breakthrough turned the Curies into celebrities, and the comical radioactivity craze that followed is one of the film's unexpected gems. "Anything you can imagine, they made with radioactivity," says Satrapi.

The film presents a slide show of historical objects so absurd it is difficult to believe they existed: radioactive matches, chocolate, toothpaste, beauty powder, cigarettes and so on.

Like the film's Marie Curie, who lies in bed cradling a luminous green vial, the public was captivated by radium's glow-in-the-dark properties. "A radium-based paint called 'Undark' was applied on everything from doorbells and house numbers to signs in mines, fishing lures, and on eyes on toy dolls," writes Nate Hendley in his 2016 book, *The Big Con*.

In 1904, a piece of musical theatre called *Piff! Paff!! Pouf!!!* took to the boards. It included a "Radium Dance", featuring dancers in the dark, clad in outfits decorated with radium paint.

"Other frightening uses of the element included radium condoms, suppositories, and facial cream," writes Hendley. People were even widely encouraged to drink water from receptacles lined with radium-infused clay.

STUDIO CANAL

There were early intimations that radiation could be used to shrink tumours, but its adverse health effects were unknown. Marie Curie kept vials of materials in her pockets and desk drawers. Astonishingly, more than a century later, her notebooks are still too radioactive to be handled without protective clothing.

"There are those that say my radium is making them sick," she says in the film. Though troubled by reports that linked radiation to sickness, the real Curie reportedly never fully admitted that her research was behind her own ill health. She died aged 66 of aplastic anaemia, a condition often caused by radiation exposure.

The emphasis on the consequences of radioactivity's discovery, both beneficial and catastrophic, was essential for Satrapi. "One question that is very

Scientific stars: Marie and Pierre Curie (Rosamund Pike and Sam Riley)

> “Curie’s notebooks are still too radioactive to be handled without protective clothing”

important for me is ethics in sciences,” she says. For her, if the purpose of science is to discover the secrets of nature, the real problem is what humans do with our discoveries.

Throughout *Radioactive*, we periodically jump forward in time. One leap is to 1957, when Gordon Isaacs became the first person to be successfully treated with a linear accelerator (essentially targeted radiation therapy), for a type of eye cancer called retinoblastoma.

Then on to Operation Nougat, a series of nuclear tests conducted in Nevada beginning in 1961, and the 1986 Chernobyl nuclear power plant disaster.

Parts of Pierre Curie’s prescient Nobel lecture, delivered in 1905, are included almost verbatim. “It can even be thought that radium could become very dangerous in criminal hands, and here the question can be raised whether mankind benefits from knowing the secrets of nature.

“The example of the discoveries of Nobel is characteristic, as powerful explosives have enabled man to do wonderful work. They are also a terrible means of destruction in the hands of great criminals who are leading the peoples towards war,” he says.

Poignantly, the speech is interspersed with a highly stylised scene of the atomic bomb dropping onto Hiroshima in 1945. It ends: “I am one of those who believe with Nobel that mankind will derive more good than harm from the new discoveries.”

Scientific progress has never been without a seriously dark side. The impact of the Curies’ discoveries reminds us of the German chemist Fritz Haber, whose work on synthesising ammonia created both modern warfare and the fertiliser that better enables us to feed the world.

The atomic bomb is perhaps one of the Curies’ dark legacies. “The bomb has more to do with the discovery of nuclear fission,” says Satrapi. “But that said, if you don’t discover radioactivity, how do you discover nuclear fission?”

Overall, *Radioactive* is stronger in its ethical provocations than in the emotional resonance of its characters. The repercussions of the Curies’ research into radioactivity are allowed to speak for themselves, but the actors can only breathe so much life into what are sketches of people.

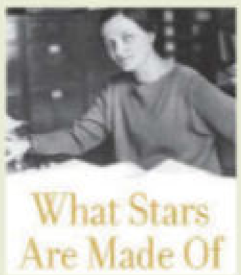
Perhaps this is the inevitable result of a struggle, especially in the case of Marie Curie, to reimagine someone we feel we know so well.

Yet, in its earnest, imperfect manner, the film portrays a luminary whose legacy remains undimmed.

Don’t miss

Watch

Vivarium lands Jesse Eisenberg and Imogen Poots in an infinitely recursive suburbia, where the smiley estate agents are not all they seem. Directed by Lorcan Finnegan, this superior sci-fi flick is out on 27 March.



Read

What Stars Are Made Of (Harvard University Press), by Donovan Moore, tells the story of astrophysicist Cecilia Payne-Gaposchkin. She worked out the chemistry of stars and was the first woman to become a full professor at Harvard University.

Play

London Games Festival is on from 26 March. More than 100,000 visitors will pitch up for the 12-day celebration of interactive entertainment. Play more than 400 titles and find out how games can be good for you.

TOP: LANDMARK MEDIA/ALAMY BOTTOM: LONDON GAMES

The TV column

The robots are back Steel-eyed murderers you can't help but root for, impossibly glamorous cities and a plot line that's a bit more linear than last time – the new season of *Westworld* is five-star viewing, says **Emily Wilson**

Emily Wilson is the editor of *New Scientist*. You can follow her on twitter @emilyhwilson or email her at editor@newscientist.com

TV

Westworld season 3

On HBO in the US and Sky Atlantic and Now TV in the UK

HBO

The *Westworld* robots are out in the real world. What could possibly go wrong?

AND we're back! Back in a sumptuous world where nothing is what it seems and we never really know who anyone is, or why they are doing what they are doing, or whether they are free agents or merely robot slaves. And yet how lovely it is to be back.

This time the violent delights of *Westworld* continue to lead to violent ends, but they also lead to a bit less bafflement. I'm only four episodes in, but the storytelling this time seems to be more linear. Which for me, having spent a lot of season two going, "HUH?", amounts to welcome respite.

My top tip is that if you have forgotten any of the 45,000 plot twists from season two, you might want to watch a recap of some kind before entering season three. Or you will have to just let it wash deliciously over you and hope that at some point you remember which Bernard you are watching (or is it Arnold, hang on, did we definitely establish that Bernard was actually Arnold?).

Season one was set in a Western-themed amusement park filled with realistic androids. That first story told how the park's robotic hosts evolved from mindless, abused creations of man into conscious creatures capable of murder. Except, of course, it was far more complicated than that.

And we could never really be sure if the hosts, or indeed the park's human guests, had much in the way of free will. In season two the revolution mushroomed out of control, partly at park HQ, partly in the cowboy park and for a time in other parks, too. It ended with utter mayhem.

> **"I say 'real' because I would be a right fool to imagine that anything is what it seems at the episode four mark"**

So to season three, now set in the "real" world. I say "real" because I would be a right fool to imagine that anything is what it seems at the episode four mark. What it seems like, though, is an impossibly glamorous, highly urbanised future world where the skyscrapers have lovely wall gardens, but elephants apparently are extinct and something has happened to Paris.

We already know from season two that the farmer's daughter-turned-warrior queen Dolores (Evan Rachel Wood) is on the outside, having seen her waved out of the park as a refugee. This most murderous and powerful of all the park hosts is a guest in our world. What could go wrong?

We also know that at least the body of baddie park boss Charlotte Hale (Tessa Thompson) has survived, given that it is the body Dolores walked out of the park in. And we know Bernard, or rather one of the Bernards, made it, thanks to Dolores. And that Dolores, who appears to have her body back, also smuggled some host minds out of the park in her bag. So there are plenty of old favourites to look out for.

Wood is as wonderful as ever as the steel-eyed murderer you can't help but root for. I've read she has a few tricks to doing Dolores, like moving her eyes to look at someone before moving her head. Whatever it is, it works. I buy this woman as a planet-busting weapon.

There are also some great additions to the cast. Aaron Paul, of *Breaking Bad*, is immediately winning as a new main character. I was a bit sick of drip/sociopath Teddy as Dolores's companion – apologies if that's heresy – so a new lead man (if he's going to be a lead, if he's a man, if he's destined for Dolores) is a good idea in my book.

It's obviously very early on to call it, but so far this is five-star TV. I can't wait to find out – maybe – what on Earth is going on. (If indeed we are on Earth.) ▮

Emily also recommends...

TV

Deadwood

If you are missing the cowboy stuff from the first two seasons of Westworld, *try* Deadwood, *the classiest cowboy show ever made. It takes a few episodes for the Dickensian brilliance to really grab you.*

Film

Men in Black: International

This is massive tosh, obviously, but I really enjoyed the performances from both Chris Hemsworth and Tessa Thompson – who also stars in Westworld.

The New Scientist Weekly Podcast

Episode eight out Friday 20th March

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neutrinos in the early universe
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Coronavirus special - the spread
of covid-19, fatality rates and the
importance of hand washing

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Pandemic preparations,
mind-reading and
a trillion trees

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The civilisation that time forgot

The discovery of a stunning culture in east Asia that rivals ancient Egypt and Mesopotamia is rewriting human history, finds **David Robson**

NEARLY five-and-a-half millennia ago, a bustling metropolis lay in the delta of the lower Yangtze, in what is now China. You could enter on foot – there was a single road through the towering city walls – but most people travelled by boat via an intricate network of canals. At its heart, was a massive palatial complex built on a platform of earth. There were huge granaries and cemeteries filled with elaborately decorated tombs, while the water system was controlled by an impressive series of dams and reservoirs.

The inhabitants of this city, known today as Liangzhu, ruled the surrounding floodplains for nearly 1000 years, their culture extending into the countryside for hundreds of kilometres. Then, around 4300 years ago, the society quickly declined, and its achievements were largely forgotten. It is only within the past decade that archaeologists have begun to reveal its true importance in world history.

Their startling discoveries suggest that Liangzhu was eastern Asia's oldest state-based society, and its infrastructure may even have surpassed the achievements of Egypt and Mesopotamia, thousands of miles to the west. "There's nothing in the world, from my vantage point, that is as monumental in terms of water management – or for that matter, any kind of management – that occurs so early in history," says Vernon Scarborough at the University of Cincinnati in Ohio. One of the biggest chapters in humanity's story, the birth of civilisation, may need to be rewritten.

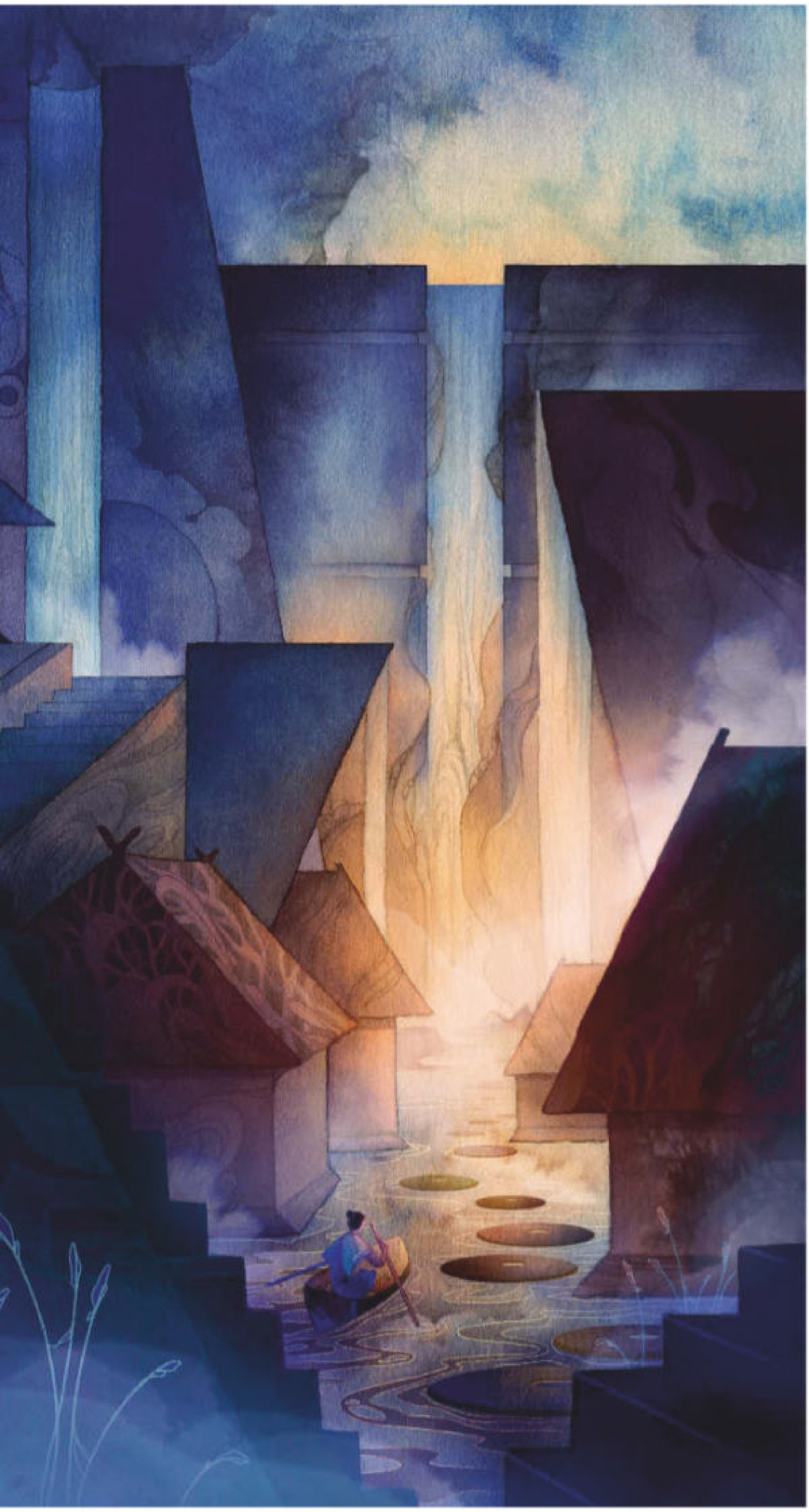
The first evidence of a lost ancient culture in the Yangtze delta was uncovered in 1936, by Shi Xingeng, who worked at the nearby West Lake Museum in Hangzhou. He named the site Liangzhu, after a nearby town. However, the black pottery artefacts he found didn't initially seem remarkable. It was only in the 1970s and 1980s that Liangzhu began to generate much greater excitement, beginning with the excavation of some cemeteries in and around the ancient city.

While many of the tombs were rather spartan, with few burial goods, some contained hundreds of beautiful jade objects, including the earliest examples of China's iconic *cong* vessels and delicate *bi* discs. Many of these artefacts were engraved with the image of a man wearing an enormous, plumed headdress, who appears to be riding a large, fanged monster – a motif that could represent a mythical or religious story. The graves also held ceremonial axes, pendants, and plaques depicting the same mythical figures, which seem to have been attached to headgear. These kinds of objects had previously been assigned to much later periods, starting with the Zhou dynasty in 1046 BC, but here they were, in a 5000-year-old, Neolithic burial place. It was the first sign that Liangzhu may have been a complex society, with workers producing costly and time-consuming artwork and a social elite rich enough to pay for it.

Later digs, inspired by these discoveries, revealed a huge earthen platform at the heart of the city. It is more than 9 metres high and covers 300,000 square metres, and appears to have supported a large palatial complex with buildings made of wood and bamboo, which the researchers named Mojiaoshan. Then came signs of city walls, more than 20 metres wide and often accompanied by internal and external moats. There was obviously an abundance of food too: one pit in the city contains more than 10,000 kilograms of burnt rice from a local granary.

Then, in December 2017, a bombshell paper

FARYN HUGHES



revealed the full extent of the society's hydraulic engineering. Using a combination of satellite photography, coring and excavations, the team led by researchers at the Zhejiang Provincial Institute of Cultural Relics and Archaeology uncovered a series of low-lying levees, built on swampy ground to control the flooding of the alluvial plain, and six "high dams" further upstream, creating reservoirs at the feet of the surrounding mountains (see "Neolithic Venice of the East", page 38).

City of canals

Together, the dams controlled the water flow in more than 10,000 hectares of land and were capable of holding back nearly 6.5 billion cubic metres of water. Carbon dating, plus an analysis of jade artefacts found near the levees, suggests that some of these dams were in operation 5200 years ago, near the beginning of Liangzhu's existence. And they were built to last: the Qiuwu high dam is still in use today.

Besides allowing Liangzhu's citizens to irrigate their paddy fields and control flooding after storm surges, the reservoirs fed 51 waterways. Made from natural river courses and artificial ditches, these canals were about 30 kilometres long in total. "Internal communication within the town must have been largely by boat; this was a town of canals as much as of roads," noted Colin Renfrew at the University of Cambridge and Bin Liu at Zhejiang Provincial Institute of Cultural Relics and Archaeology in a 2018 paper. Perhaps the closest comparison is medieval Venice or one of the "water towns" around Shanghai that emerged thousands of years after Liangzhu and that attract tourists to this day.

The canal system was also used to transport building materials, including timber and rocks, down from the nearby mountains and into the city through its eight water gates. Foundations for the city walls, for instance, appear to come from mountains to the north. "These stones were not quarried per se using tools to cause physical breakage, but collected from the surface," says Yijie Zhuang at University College London, a co-author on the 2017 paper.

While research in Liangzhu continues apace, discoveries elsewhere in China indicate that the civilisation's rise was part of a broader social and cultural revolution. Recent archaeological studies show that, starting more than 5000 years ago, many settlements were emerging in the lower and middle Yangtze regions, in what is now Sichuan province and along the lower Yellow River. Some, including Shijiahe in the middle Yangtze, are large enough to have

> **"One of the dams in operation 5200 years ago is still in use today"**

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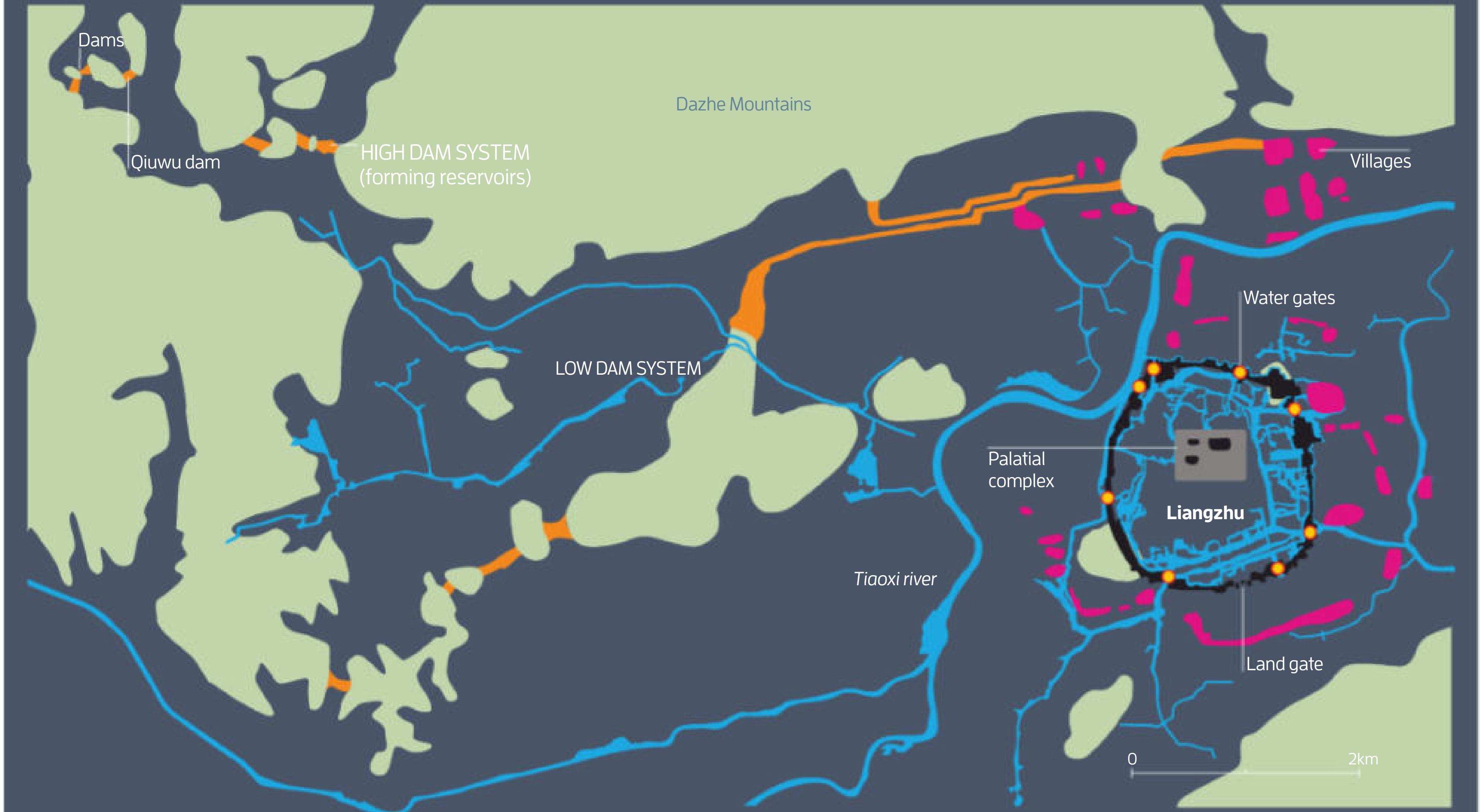
Neolithic Venice of the East

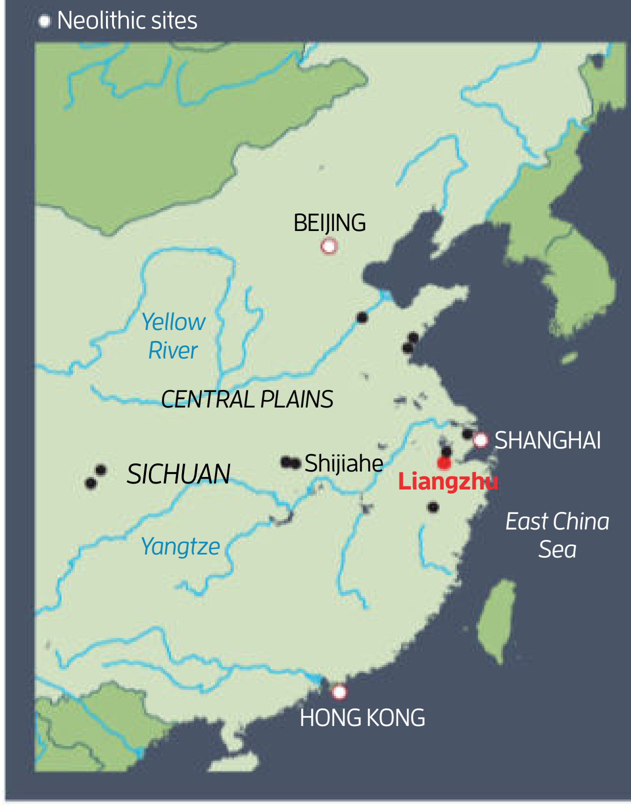
Between about 5500 and 4300 years ago, the inhabitants of Liangzhu used sophisticated hydraulic engineering to control the surrounding floodplains and feed a system of canals within the walled city



SOURCE: DOI.ORG/GF77XT

China's original cultural revolution

Starting more than 5000 years ago, many settlements arose along the Yangtze and Yellow rivers and in what is now Sichuan province. Although none was as large and sophisticated as Liangzhu, they point to an early culture that is rewriting Chinese prehistory



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Artefacts found at Liangzhu include black pottery (far left) and jade vessels (left and below)

Neolithic hydraulic engineering around Liangzhu has no equal in the ancient world

MAIN IMAGE AND ABOVE: XINHUA/ALAMY

AGEFOTOSTOCK/ALAMY

required organised labour to build their moats and walls. “Liangzhu is by far the biggest, but you find other walled urban centres,” says Jessica Rawson at the University of Oxford. “And you get high levels of craftsmanship, not just in jade, but in several types of ceramics, in several parts of China.” There will have been communication between some of these sites, with the larger settlements acting as local power hubs. Liangzhu’s cultural influence, for instance, can be found in rural sites more than 100 kilometres away.

This paints a very different picture from the traditional view of Chinese history. Small rice-farming communities began to appear around 10,000 years ago. Until recently, however, it was thought that the first Chinese state society – one with a formal political system and complex social organisation – emerged just 3600 years ago, with the rise of the Shang dynasty in the Central Plains. But Liangzhu, far to the south-east, has many of the features of a state society around 1700 years earlier, argue Renfrew and Liu, who has conducted much of the archaeological research at the site.

Hallmarks of state

First, there is the size of the population. Liu’s team estimates that this peaked at between 22,900 and 34,500, which is many times larger than any earlier Chinese community. Then there is clear evidence of a strict social hierarchy, such as the vast differences between the tombs of the rich and the poor. Finally, there is the ambition of the communal works, including the building of the city walls, the Mojiaoshan platform and palatial complex, and the sophisticated hydraulic engineering.

The construction work is particularly impressive when you consider that the city’s inhabitants had no pack animals, such as horses or donkeys, or oxen to pull a plough, says Rawson. Nevertheless, they were able to relieve enough people from their agricultural duties to build these monumental structures. “Everything is dependent on human labour,” says Rawson. “And the key thing then is to organise that labour.” Liu’s team has estimated that constructing the dams alone would have required the movement of around 2.9 million cubic metres of earth, which would have taken 3000 workers eight years to complete. This was a huge undertaking, of the kind that can only come from a sophisticated society with central organisation and planning. “You can’t think of this hydraulic project without planning,” says Rawson. “This is not a small group of people – this is large-scale management.”

›

Cradles of civilization

Discoveries in China point to a previously unknown civilisation in east Asia. How does Liangzhu measure up to other early human civilisations?

To archaeologists, a civilisation is an urbanised state society with central settlements in the form of towns and cities, and complex social organisation, such as a class system or a ruling elite. Civilisations also have some control over the environment, so that people are more resistant to the whims of nature and can create a surplus of food that allows various industries to flourish. By-products of this way of living include writing, long-distance trade and monuments.

The so-called Fertile Crescent east of the Mediterranean has often been called “the cradle of civilisation”, thanks to the emergence of city-states such as Uruk in Mesopotamia, which became increasingly urbanised from around 6000 years ago. Estimates of Uruk’s population vary wildly, but, by around 4900 years ago, it is thought to have housed more than 60,000 people. Its communal works included temples and canals for irrigation. Uruk’s inhabitants invented the first known form of writing, cuneiform, and their texts include the earliest surviving great work of literature, *The Epic of Gilgamesh*, about a legendary king of the city.

At the western end of the Fertile Crescent, another civilisation was emerging at about the same time. Farming communities in Egypt also became increasingly urbanised and, by 5100 years ago, they had coalesced into a society ruled from the city of Memphis by the first pharaoh, Narmer. This “first kingdom” used the waters of the Nile for irrigation, had elaborate tombs – although not yet as ambitious as the famous pyramids – and a rudimentary writing system based on hieroglyphics.

We now know that complex societies were developing independently elsewhere, though. The Indus valley in south Asia, for instance, became increasingly urbanised between 6000 and 5000 years ago, with the formation of cities such as Harappa, home to tens of thousands of people. Intriguingly, there seems to have been some communication and trade between the people of Harappa and Mesopotamia. It isn’t yet clear, however, whether the symbols found on Indus valley artefacts constituted a fully fledged writing system.

The Liangzhu culture on the lower Yangtze had much in common with these early civilisations. With its social elite, skilled craftwork and refined architecture, it demonstrated the most important characteristics of a state society more than 5000 years ago. Its population of up to 34,500 put it on a scale with Uruk, Memphis and Harappa. And its communal works would have required large-scale social organisation and management. Liangzhu’s enormous hydraulic system, which allowed its citizens to master their watery landscape, was so advanced that some consider it the most impressive anywhere in the world at that time. It is time to abandon the idea that civilisation had a single cradle.

> **“It is time to abandon the idea that civilisation had a single cradle”**

The people of Liangzhu created beautiful jade objects long before they were seen in other areas

IMAGINE CHINA LTD/ALAMY

Even on a global scale, Liangzhu's waterworks were truly groundbreaking. The Middle East is often considered the cradle of civilisation, with a handful of urban societies, such as Tell Brak and Uruk in Mesopotamia, emerging in the fourth millennium BC. These cities had developed water management technology, but their engineering didn't match that of Liangzhu in size or complexity. As Liu and Renfrew put it: "[Liangzhu's dams] may be the earliest communal works achieved anywhere in the world on such a scale." Scarborough agrees. He visited the site in 2017 and was awestruck by how the citizens of Liangzhu had completely reshaped their environment. "It's an engineered landscape that is second to none, given its antiquity."

There is just one surprising absence at Liangzhu. So far, archaeologists have failed to find clear evidence of writing, which is sometimes considered a prerequisite of a fully formed state society. However, it is possible that some symbols found on the pottery and jade aren't simply decorative. Chunfeng Zhang at the East China Normal University in Shanghai says they have some linguistic features. Some of the 656 symbols documented so far are highly standardised in form, and many regularly appear across different sites at the same points on certain artefacts, such as the leg or mouth of a vessel. This suggests they may have a consistent meaning, like a label. Zhang also points to apparent rules in how certain symbols are constructed, which may have changed their meaning. These include the addition of new strokes and the systematic combination of different motifs, which again hints at a nascent writing system. "Some symbols have only decorative functions, some of them represent meaning and for some of them it is difficult to determine the function," she says.

Zhang hopes we may one day find the equivalent of a Rosetta Stone to decipher the symbols at Liangzhu. Even without one, the culture rivals other very early societies (see "Cradles of civilisation", page 39). With further research, Liangzhu might even shed light on the processes that led humanity to develop complex urban societies. The move from a hunter-gatherer to a farming lifestyle is one known force for the establishment of early settlements, as groups began to congregate around fields. Eventually, farmers pooled resources, collaboration and cooperation increased, and communities grew. But what pushes a society to make the final leap to a large urban centre with more advanced technology, architecture and politics?

Scarborough argues that environmental uncertainty played a central role in Liangzhu. This included the risk of flooding in the wet season, and drier periods that would have destroyed the paddy fields. This uncertainty might first have encouraged the establishment of more regular religious practices that brought dispersed groups together for ceremonies. The depictions of a fearsome monster on artefacts across the region suggest the existence of some kind of shared mythology. Organised religious practices may, in turn, have encouraged the establishment of stricter social norms and even leadership roles for people who seemed able to predict or control the weather, for instance.

> **"Liangzhu might even shed light on the origins of complex urban society"**

The formation of a social hierarchy could then have helped to mobilise a large workforce for more practical communal projects such as dam building. While this would have brought greater cohesion and prosperity for the whole community, it would also have helped to cement the elite's power by allowing them to control who had access to the technology and who could enter or leave the city by its canals. The result was a society with a formal government, and with sufficient wealth to create elaborate artwork and architecture.

Scarborough believes environmental uncertainty played an key role in the formation of civilisations in the Middle East too – although the main threat there was drought. "It was more the rerouting of a limited amount of water off the Tigris or Euphrates to accommodate the sizeable cities that were beginning to spring up," he says. In each case, the need to control the environment prompted greater cooperation and also gave power to an elite, promoting a new kind of social organisation. "Water [management] is not the only trigger for social complexity, but it's certainly a primary one," he says.

If flooding was a trigger that set Liangzhu's development in motion, it may also have been its downfall. Analysing layers of sediment in the region, Zhanghua Wang at the East China Normal University and her colleagues found evidence of repeated marine flooding beginning around 4500 years ago, with deposits of algae and small marine fossils directly on top of the layers associated with the Liangzhu culture. The damage caused by the flooding, and the increased salinity would have made rice cultivation more and more difficult throughout the region, she says, undermining "the most important economic and social foundation of the Liangzhu society".

While the society itself collapsed, its influence appears to have lingered as the inhabitants moved to other parts of what is now China. Liu and others believe that elements of Liangzhu's culture, such as the design of its jade *congs*, were borrowed and adopted by later societies. And the local landscape has forever been changed by the impressive hydraulic engineering. Flooding might have spelled the end of life in the city but its citizens left an indelible mark. And, with the ongoing archaeological excavations, this amazing culture is changing our ideas about the dawn of civilisation. ■

David Robson is a science writer and author of *The Intelligence Trap*. His website is www.davidrobson.me

Not so waspish

They are one of the least loved animals, but wasps deserve our affection. It's time for a rebranding, argues entomologist **Richard Jones**

LESSY DOANG/GETTY IMAGES

Many people equate "wasps" with these yellow-and-black insects, but there are over 100,000 species

EVERYBODY loves bees. They are celebrated for their glorious honey, cooperative work ethic and commercially valuable pollination services. In a 2019 survey, 55 per cent of respondents chose bees as the species they most wanted to save, above the likes of elephants and tigers.

How differently we see wasps. These most unwelcome picnic guests have been reviled for millennia. Ancient Greek essayist Plutarch described wasps as degenerate bees. The very word "waspish" summons up ideas of irritability, implying they are quick to anger, spiteful and vindictive. And that's just the regular wasp or yellow jacket. Our attitudes to the largest wasp species, hornets, are even more negative. The tabloids hawk horror stories about how the invasive Asian hornet, *Vespa velutina*, threatens honey production and native pollinators in the UK. Meanwhile, persecution of the huge but docile European hornet, *Vespa crabro*, continues, fuelled by fear and ignorance, even though its numbers are declining. Few people seem to care.

But are we judging this diverse group of insects unfairly? Certainly, our perceptions are ill-informed. There are whole institutes dedicated to studying bees, while wasp research is in the doldrums. Limited funds attract few projects, the results of which are often misconstrued in the press, bolstering an already negative stereotype. In fact, what we have learned about wasps tells a different story. Far from being bothersome and vindictive, they make valuable contributions to ecosystems, the economy and even our health.

Take ecosystem services – a buzz phrase of our time that means the quantifiable

›

What is a wasp?

Say "wasp" and most people think of social wasps of the family Vespidae, often called yellow jackets in North America. These relatively large, mostly black-and-yellow species live in colonies of between 50 and 10,000 individuals and inhabit nests of paper-like material made from chewed wood pulp. Yet they comprise less than 4 per cent of more than 110,000 known wasp species.

And less than a third of wasp species have evolved what we tend to think of as the defining wasp characteristic: that painful sting. Stinging species are predatory, whereas the remainder are parasitic. And the vast majority of wasp species are solitary, often living secretive lives that are easily overlooked.

Wasps come in myriad varieties. Pale, flimsy fairy wasps parasitise insect eggs. As little as 0.14 millimetres long, they are possibly the smallest insects. Ant-like gall wasps have chemicals in their stings that induce bizarre growths called galls on plants. Their offspring then develop within these structures, which include ball-like oak apples on oak trees and moss-like robin's pin-cushions on some shrubs. Spider-hunting wasps stock a burrow with paralysed but living arachnids on which their larvae then feed. Potter wasps make nests of mud. Mason wasps burrow into loose mortar. And ichneumon wasps lay their eggs inside moth caterpillars.

Whatever form they take, wasps – along with bees, ants and a whole host of other svelte, narrow-waisted insects – belong to the order Hymenoptera, from the Greek meaning membrane-winged. These insects have four wings, a larger front pair and a smaller back pair latched together by a row of microscopic hooks (the hamulus) to make a more efficient single aerofoil. However, they don't adhere to the conventional three-part insect body plan of head, thorax and abdomen. Instead, the first segment of the abdomen is fused to the thorax to create a compound body called the mesosoma. Then there is a narrow, stalk-like waist between the mesosoma and the rest of the abdomen. This acts like a universal hinge, allowing the posterior section to be pointed in almost any direction, which is particularly useful for species with a sting in the tail.

Vespidae wasps shared a common ancestor with bees some 175 million to 200 million years ago. The main difference between them is that bees feed exclusively on nectar and pollen, whereas wasps have more wide-ranging tastes. Adults may visit flowers to take the odd sip of nectar for energy, but small insects are the main source of food for wasps and their larvae, and they aren't above dining on carrion and ripe animal scats. With bee species numbering a mere 25,000, you might even say that they are just specialised, vegan wasps.

> "With a quarter the number of species, you might say that bees are just specialised, vegan wasps"

benefits nature provides for us. Honeybees may be the prime pollinators of many cultivated fruit crops, but wasps and other insects pollinate most wild flowers. Indeed, some plants rely exclusively on wasps. Among them are almost 100 species of orchids, including helleborines. These widespread but scarce plants of woodland edges have a cunning trick to entice pollinators. Their flowers produce the sort of volatile chemicals that other plants emit when under attack from caterpillars, which lure predatory wasps hoping to find prey. The wasps then sip the nectar in the orchid flowers, which contains soporific agents – possibly alcohol from fungal contaminants – that slow them down, increasing the likelihood they will pick up pollen. Without their tipsy wasp pollinators, these elegant plants would become extinct.

Pest control

Wasps also benefit us even more directly. They are the third most important predators of insects after birds and spiders. They use their powerful triangular jaws to kill prey, snatched from plants or from mid-air. Once the victim's nutrient-poor wings are scissored off, the dismembered bodies are taken away to feed to the ravenous brood back in the nest. A mature wasp colony is reckoned to take between 3000 and 4000 prey a day at the height of the season. By one estimate, in the UK alone, wasps eat 14,000 tonnes of insects each summer.

They target woodlice, spiders, flying beetles and, less endearingly, butterflies and honeybees. But they also make quick work of many serious crop pests, including aphids, caterpillars, plant bugs and flies. There have long been anecdotal reports of plagues of flies on private estates after overzealous wasp nest clearances. In the early 20th century, small, umbrella-shaped nests of paper wasps were placed around Caribbean cotton fields to control infestations of voracious moth caterpillars called cotton bollworms. Likewise, in the sugar cane fields of the Philippines, paper wasps were used to help suppress sap-sucking planthoppers. Recent research reveals that another paper wasp, the provocatively named *Polistes satan*, can control the larvae of two of the world's most rapacious pests, the sugar cane borer and the fall armyworm, which eats crops including maize.

Even the sting in a wasp's tail has potential to help us. Wasp venom evolved to kill prey, but social species also use it for defence. Their succulent, protein-rich grubs are a favourite of the misnamed honey badger and honey

SUPERSTOCK/ALAMY

> **“Some orchids would become extinct without their tipsy wasp pollinators”**

Some wasps, like *Cosmosoma myrodora* (left), pollinate flowers. Others might help treat diseases, including *Polybia paulista* (above), whose venom can kill cancerous cells

buzzard, among other animals. Subterranean nests are their preferred targets and, to protect themselves while digging out wasp grubs, honey badgers have dense shaving-brush bristles on their snouts while honey buzzards have small, dense guard feathers around their faces. As the defences of predators have evolved, so too has the potency of wasp venom to keep them at bay.

Partly as a result of this evolutionary arms race, a wasp sting is a potent weapon. On average, a sting delivers 15 microlitres of venom – a complex cocktail of bioactive molecules that varies from species to species. It includes histamines to increase blood flow, proteases and lipases to rupture flesh and blood cells, and neurotransmitters to confuse and overstimulate nerves. Humans may not be the intended target, but a single wasp sting can raise a welt the size of half a ping-pong ball. Multiple stings can cause redness, nausea, vomiting, wheezing and confusion. If you receive over 100 of them, you should seek emergency medical help: there is no antivenom, but dialysis can remove the toxins from the blood before significant organ damage occurs. The average adult would be lucky to survive 1000 or more wasp stings.

Paradoxically, however, venoms often have medical applications. Although little research has been done on wasp venom, it is likely to be no exception, if bee venom is anything to go by. There is a long tradition of beekeepers accidentally (and deliberately) courting bee stings to get relief from the pain of rheumatoid arthritis. Tests in animals confirm that administering bee venom reduces the severity of arthritis. This may work by stimulating the immune system or increasing the release of corticosteroids, which quell inflammation.

Therapeutic venom

Being more varied than bee venom, wasp stings may prove even more useful as a source of medicines. Several active ingredients already show promise. An extract of the venom of the large, black Brazilian wasp, *Polybia paulista*, for example, disrupts and kills cancer cells (in mice, at least) by attaching to particular lipid molecules in their membranes. This extract is one of a class of wasp venom components called mastoparans.

Even more promising is another type of mastoparan. It latches on to specific lipids too, so could be used to rupture cell membranes in targeted body tissues, either to destroy cells or to create portals for pharmaceuticals to get into them. It also shows encouraging antibacterial and antiviral qualities, and inhibits the development of the parasite that causes Chagas’ disease. Further wasp venom constituents are being explored as treatments for neurological conditions, allergies and cardiovascular disease.

As if all this weren’t enough, wasps can play a role in conservation too. They are affected by climate change, intensive agricultural practices and the same pesticides that are implicated in a widespread decline in insect numbers. All this makes them good indicators of environmental stress, if we can track their fate. In 2017, the Big Wasp Survey was launched in the UK to do just that. It is a citizen science project that aims to map the diversity and location of wasps by sampling specimens using traps in gardens all over the country and comparing year-on-year numbers of species and individuals.

Our ignorance about wasps is still vast but, by looking beyond our prejudices, we can see their potential to tackle some of the biggest problems we face. A wider understanding of their diversity (see “What is a wasp?”, far left), life histories, ecologies and behaviours is long overdue. It is time we stopped demonising wasps and learned to love them. ▮

Richard Jones is a London-based entomologist and writer. His book, *Wasp*, is published by Reaktion Books

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Race for a vaccine

With the coronavirus pandemic getting worse, we are turning to new techniques to deliver a vaccine in record time. Can it be done, asks **Carrie Arnold**

POTTERING around her kitchen on the morning of 31 December, Kate Broderick scrolled through the headlines while she waited for her tea to brew. One story caught her eye: a mysterious outbreak of severe pneumonia in Wuhan, China. Nearly overnight, the number of cases seemed to explode. "I knew we didn't have time to wait," she says.

A molecular geneticist at Inovio Pharmaceuticals in California, Broderick was poised for what came next. When Chinese officials published the genetic sequence of the new SARS-CoV-2 coronavirus causing the illness just two weeks after the first cases were reported to the World Health Organization, Broderick got to work. Within 3 hours, her team had a prototype vaccine ready for initial testing. It was an unprecedented turnaround, but a moment Broderick and many others had long seen coming.

Making vaccines usually takes a decade or more between development, safety testing and manufacturing, says Seth Berkley, head of Gavi, an international group that promotes vaccine use around the world. With global confirmed cases of the new disease, covid-19, surging past 180,000 as this went to press, time is of the essence.

To speed things up, scientists are turning to untested classes of vaccines, and rethinking every part of how they are designed, evaluated and manufactured. If the approach works, we

> “The fastest we have cranked out a vaccine in response to an outbreak is five years”

will, for the first time, have identified a new disease and developed a vaccine against it while the initial outbreak is still ongoing.

But speed can come with downsides. “We could have a vaccine in three weeks, but we can’t guarantee its safety or efficacy,” says Gary Kobinger, a virologist at Laval University in Canada.

The hope is to have at least 1 million doses of coronavirus vaccine available to the public in 12 to 18 months, according to Melanie Saville. She is head of vaccine development and research at the Coalition for Epidemic Preparedness Innovations (CEPI), set up in 2017 with funding from the Bill & Melinda Gates Foundation, the Wellcome Trust and several governments. Until now, the fastest we have ever cranked out a vaccine in response to an outbreak was with Ebola – and that took five years, says Berkley. Eighteen months to make a new vaccine widely available is “naively optimistic”, says Kobinger. It isn’t impossible, but it may mean ripping up the rule book.

All vaccines work by tricking the body into believing it has been exposed to a pathogen. This causes the immune system to respond with antibodies and T-cells to neutralise or kill the invader. Afterwards, some of these remain in circulation, ready for action in case you are exposed to the actual infection. In other words, your immune system is primed.

The more closely a vaccine mimics the disease, the more protection it will provide. We currently have four main strategies for pulling off this trick. Live-attenuated vaccines use actual viruses or bacteria that have been altered to prompt an immune response but not full-blown illness. Inactivated vaccines are exactly what they sound like: they are made by growing huge amounts of the pathogen in vats, which is then inactivated – or killed – with heat or chemicals. Both these strategies are used with flu vaccines, for instance.

The third variety, toxoid vaccines, are used against bacteria that cause disease indirectly, by producing a toxin, as is the case with tetanus, diphtheria and botulism. They contain a piece of the toxin that readies your body’s response to the full thing. Lastly, subunit vaccines contain just the small pieces of a pathogen that activate the immune system, which can be polysaccharides (sugars), proteins or a combination of these, called a conjugate. These subunits are made by producing the right sugars and proteins in large vats using engineered bacteria or yeast, then painstakingly removing impurities.

These key vaccine types have been around for decades and have an established safety record, but it can still take up to 15 years to go from prototype to general use, says Berkley (see “How to make a vaccine, step by step”, page 46). Two main factors are behind long development times: historically, scientists have spent years studying how a pathogen interacts with the body and the immune system before developing a vaccine; and fewer than one in four candidate vaccines that start clinical trials make it through the whole process and get licensed for use, he says.

A head start

In principle, the tried and tested nature of these approaches should give them an advantage in the sprint to develop a vaccine against the new coronavirus, says Maria Bottazzi at Baylor College of Medicine in Texas. While these vaccine types typically take years to develop, their established safety profile could mean fewer, shorter trials in people.

And getting out of the starting blocks has become easier. New approaches to vaccine development allow us to dramatically shorten the first step in the process. For the new coronavirus, researchers like Annie De Groot, co-founder of the biotech company EpiVax in Rhode Island, used computational models that can jump directly from the genetic sequence to a potential vaccine by zooming in on those parts of the virus that would be good vaccine targets. As soon as SARS-CoV-2 was sequenced, researchers at labs around the world were able to jump in and get to work figuring out what made it tick and how to fight it, says Florian Krammer, an infectious disease and vaccine specialist at Mount Sinai School of Medicine in New York. Like Inovio, many had mock-ups of prototypes ready within hours. Such advances have been a long time coming. “It took us 21 years of work to be able to develop a vaccine in 3 hours,” says De Groot.

How to make a vaccine, step by step

It is a race against time to develop a vaccine amid a pandemic. Each step, detailed below, usually takes months to years. An Ebola vaccine broke records by being ready in five years. The hope is to develop one for the new coronavirus in an unprecedented 12 to 18 months.

Develop a prototype
This usually takes years, depending on the technique used. With the current coronavirus outbreak, companies had prototypes within hours thanks to new technologies that can identify which bits of a virus might be used in a vaccine.

Animal trials
These are primarily to demonstrate safety and to test the immune response generated by a vaccine. In some cases, this stage can be skipped altogether, but there may be safety trade-offs.

Phase I human trials
These are the first tests in people, usually involving 20 to 80 individuals and are used to demonstrate safety and ensure any side effects aren't too severe.

Phase II human trials
This requires larger groups of people and is used to test efficacy. Some vaccines can skip from here to regulatory approval when there is urgent need.

Phase III human trials
At this stage, a new vaccine is tested on hundreds to thousands of people, to clearly evaluate both efficacy and safety.

Regulatory approval
After examining clinical trial evidence, regulatory bodies determine whether the vaccine can be licensed for public use. This may come with the requirement that follow-up safety data be gathered.

Mass production
At this point, manufacturing of a vaccine is ramped up under strict quality control and consistency standards.

Public access
When the new vaccine becomes available, governments and public health authorities have to determine which groups of people get it first.

Matthew McKay at Hong Kong University of Science and Technology is one of those taking advantage of such leaps. He and his team looked at genetic similarities between the new virus and another, earlier coronavirus that shares up to 90 per cent of its DNA: SARS-CoV, the one that caused a SARS outbreak in 2003. Their work on SARS showed that the human immune system responded most strongly to the protein spikes that form the crown, or corona, surrounding the virus and to the proteins that envelop its nucleus. McKay's team also found that one in five of the sites that the immune system could recognise, known as epitopes, were identical between the new coronavirus and the earlier SARS one. His team published that work in February (*Viruses*, doi.org/ggm4nr). "This says these appear to be important targets for a vaccine," says McKay. An independent lab published similar findings last week.

This initial flurry of work has yielded at least 35 candidate vaccines, six backed by CEPI. In the wake of earlier epidemics such as Ebola, MERS and SARS, CEPI was created to help us respond better – and faster – by having rapid response systems at the ready.

Many of these use the well-established vaccine types, but hope to accelerate the usual timelines by streamlining each step in the process, most notably prototype development. For example, CEPI is funding a collaboration between EpiVax and the University of Georgia to use the results of the company's computer modelling to genetically engineer a segment of the virus into a subunit vaccine, like the one used for hepatitis B worldwide. Bottazzi's team at Baylor is developing a similar vaccine.

Janssen, a pharmaceutical company owned by Johnson & Johnson, has begun work on a possible vaccine using a harmless, genetically engineered adenovirus. That is the same strategy the firm used for Ebola.

Another CEPI-funded initiative uses technology developed by researchers at the University of Queensland in Australia to stabilise the coronavirus protein subunit that would be used in a vaccine and so improve its ability to generate an immune response. The university already has its vaccine in animal trials, according to Saville.

But the tried-and-tested vaccine types aren't the only game in town this time. Inovio, for example, aims to use nucleic acids like RNA or DNA in its vaccine. Although neither DNA nor messenger RNA (mRNA, which helps the body translate genes into protein) create an immune response directly, these vaccines get cells to make the proteins that will create a response.

"Instead of producing viral proteins in a factory, we're injecting RNA and letting your cells be the factory," says Joe Payne, head of Arcturus Therapeutics, one of the companies using this approach.

JALAA MAREY/AFP VIA GETTY IMAGES

Once the DNA or mRNA enters a cell, the person's own protein-making machinery takes over. DNA vaccines must be converted by cells into mRNA first, whereas mRNA allows you to skip this stage. Depending on the genetic code used, the resulting viral protein made in the body can be secreted from muscle or skin cells, displayed on the cell's membrane, or be embedded in the membrane itself. These strategies trick the immune system into thinking the body has been invaded by a pathogen, which leads to the creation of T-cells and antibodies – or so the theory goes. So far, no such vaccines have been approved.

A major hurdle with these vaccines is getting the DNA or RNA into cells, as our blood is filled with enzymes that can chop these substances into bits within seconds. Each company pursuing this approach has developed its own technology to circumvent this problem. Arcturus and a Massachusetts-based biotech

> "It took us 21 years of work to be able to develop a vaccine in 3 hours"

In labs all over the world, the hunt for a way to beat the new coronavirus is gathering pace

firm called Moderna are enveloping the vaccine's genetic material in a protective core, while Inovio is administering a tiny electrical current at the injection site to encourage nearby cells to swallow DNA whole. All three have said they will be able to rapidly scale up production. Moderna has already recruited people in Seattle for an early-stage clinical trial to test for safety. The trial, which will include 45 healthy volunteers, began on 16 March.

"It's a crazy, awesome speed, beyond what we saw with Ebola," says Kobinger.

The safety and efficacy of these new types of vaccines remain unknown, and there are concerns that DNA-based vaccines might affect our own genes or somehow spur harmful immune reactions. As of 17 March, none of the companies had released detailed data about the immune responses generated in animal models or any potential adverse events.

Moderna is also taking its RNA-based vaccine, mRNA-1273, directly to human trials before completing standard toxicological testing in animals. The firm is relying on safety testing already completed for its other mRNA vaccines in development.

Yet with any new vaccine, there are concerns about something called "immune enhancement". This can happen when a prior vaccination or infection inadvertently facilitates a virus's ability to enter cells and make copies of itself. It means that instead of protecting you, the vaccine could make you vulnerable to more severe infection. Harmful immune enhancement was seen in early animal trials of SARS vaccine and in human trials of a vaccine for a respiratory virus called RSV.

These types of concerns, and the track record of very few vaccines making it from clinical testing through to approval for use in humans, are what make lengthy clinical trials so necessary, says Johan Van Hoof, head of infectious diseases and vaccines for Janssen. Older vaccine technologies have an advantage as they have already been vetted. "It gives a certain level of comfort that you can use these [older] vaccines in an emergency and you already have a solid safety database," he says.

Striking the balance between speed and safety is always going to be a challenge. If a vaccine takes too long to develop, the initial outbreak may be over, which creates its own set of problems. For example, by the time clinical trials of an Ebola vaccine were under way during a large outbreak that began in West Africa in 2014, disease transmission had slowed so much that researchers couldn't treat enough people to gather the robust data needed for regulatory approval. Only after a larger outbreak and a bigger trial was there enough evidence to prove safety and efficacy, says Kobinger, who worked on that vaccine, called Ervebo. It was finally approved by the European Medicines Agency in November 2019.

Left in limbo

None of the other vaccine candidates for Ebola made it as far. The rest, says Greg Poland at the Mayo Clinic in Minnesota, were stored in freezers, unable to find funding quickly enough to even begin testing. No SARS vaccine made it beyond phase I safety trials before the disease vanished and funding dried up.

Money is also critical to vaccine development. "Scientists need to be assured of research funding. Science is not a spigot you can turn on and off," says Poland.

In part, it was the stark realisation during the West African Ebola outbreak that Big Pharma could no longer be relied upon to solely underwrite expensive vaccine research – especially for diseases with little chance of recouping the outlay – that prompted governments and NGOs to seek an alternative. "The formation of CEPI has been a paradigm shift," says Broderick. "Before that, everything was completely reactive."

CEPI's strength isn't only funding research, but also pairing small, innovative biotech firms with the might of established drugs companies. The coalition has funded efforts to develop vaccines against Lassa fever, Zika and Nipah, and even to prepare for "Disease X", the World Health Organization name for any unknown infection that may yet emerge – precisely the situation that arrived with the new coronavirus. CEPI-funded scientists also worked on vaccines against MERS, a coronavirus spotted in 2013 and closely related to SARS, both of which can cause pneumonia.

So when the first reports of severe pneumonia caused by the new coronavirus began trickling out of China, CEPI was ready for action. But it, too, needs a steady supply of funds. Saville estimates that $350 million will be required in just the next few months to meet the accelerated timeline of creating a vaccine for covid-19 within 12 to 18 months.

Given the all-consuming nature of the current pandemic, there is good reason to believe CEPI will get the money it needs. From there, it is a matter of seeing which vaccine options make it through the many steps to eventual regulatory approval. When one does, then the final challenge will be to rapidly scale up manufacturing to produce millions of doses to exacting medical standards.

All these steps are hard enough when there isn't an outbreak, says De Groot, and no one can say how the pandemic will affect supply chains and labour pools related to vaccine development. It is also possible that, by the time a vaccine is ready for late-stage clinical trials, there won't be enough virus circulating to provide firm answers about its efficacy.

So how realistic is the 12 to 18-month timeline? "It's still fairly aspirational," says Saville. It is based on everything going well and faster-than-ever progress through each step in the process. In other words, it is a long shot.

The teams making vaccine candidates know every minute counts. Broderick says the rising number of cases and deaths rattle through her head from the moment she wakes up.

She and others have no doubt that we will eventually have a vaccine against covid-19. It is just too early to say which candidate will be ready first, or what problems we may hit along the way. It could be a bumpy ride, says Poland. "We're building the plane as we're flying." ▮

Carrie Arnold is a science writer based in Virginia. Follow her @edbites

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NIH-funded postdoctoral position immediately available to study physiological functions and pathological alterations in arterial smooth muscle and endothelial cell ion channels. Projects include studying blood pressure regulation by ion channels and regulation of trafficking, signaling and functions of TRP, BK_{ca}, K v and voltage-dependent Ca^{2+} channels, similar to studies we have recently published (Kidd et al. Science Signaling 2015, Leo et al. Science Signaling 2017, Bulley et al. eLife 2018, Hasan et al. PNAS, 2019). Techniques in the laboratory include, RT-PCR, Western blotting, biotinylation, immunofluorescence, FRET, patch-clamp electrophysiology, calcium imaging, pressurized artery myography, blood pressure telemetry and conditional knockout mouse models. Experience with molecular biology, ion channel biochemistry, patch clamp electrophysiology, and cardiovascular physiology preferred. Required qualifications include a PhD or MD in Physiology or a related field.

Send curriculum vitae and names and addresses of three references to Dr. Jonathan H. Jaggar, Maury Bronstein Endowed Professor of Physiology, Department of Physiology, University of Tennessee Health Science Center, 894 Union Avenue, Memphis, TN 38163, USA. **jjaggar@uthsc.edu**. https://www.uthsc.edu/physiology/faculty /jjaggar. php

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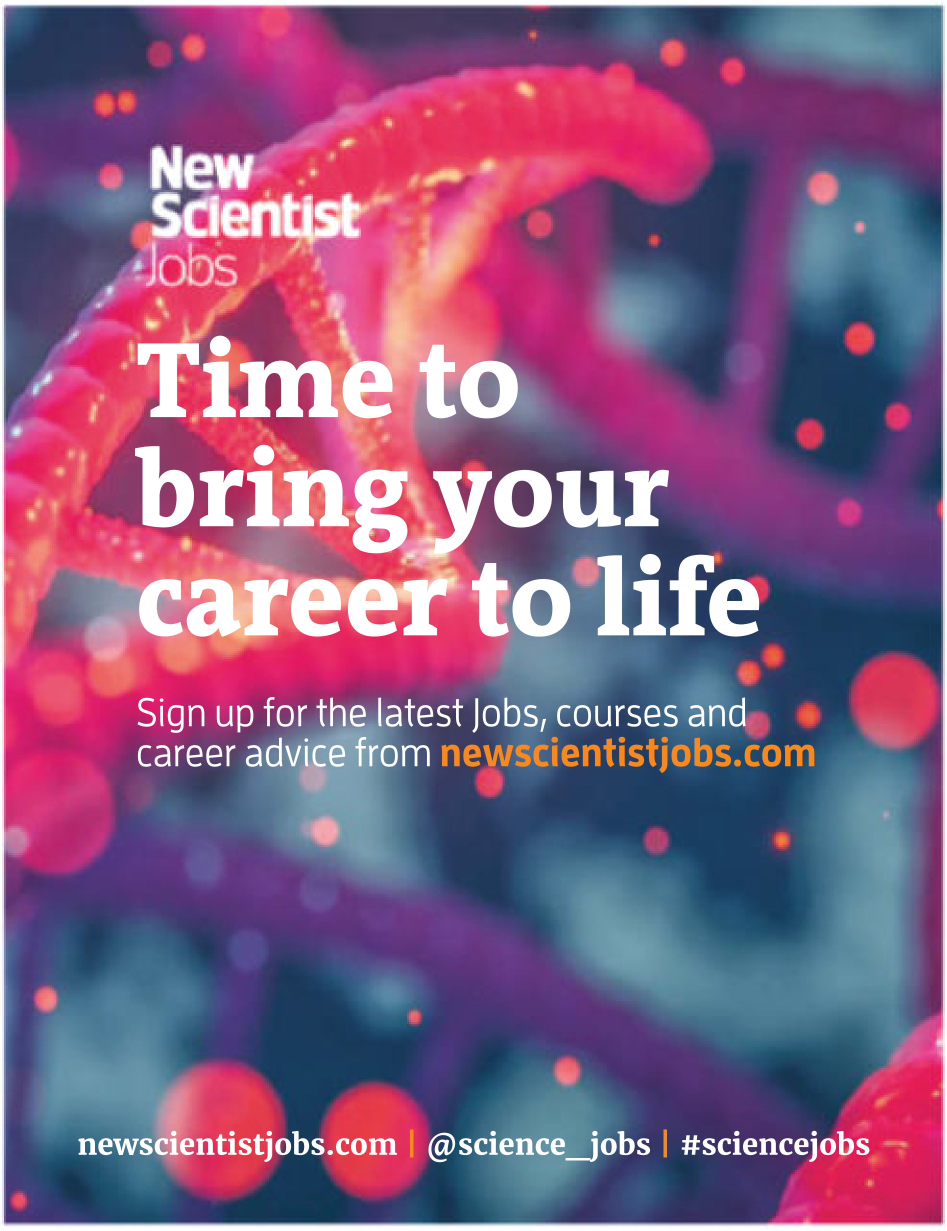

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Marine Biological Laboratory

THE UNIVERSITY OF CHICAGO

The Ecosystems Center of the Marine Biological Laboratory (MBL) is hiring faculty at all levels to expand our program in coastal ecosystems ecology. Scientists with an interest in collaborative, interdisciplinary studies on coastal estuaries, bays, marshes, and/or coastal watersheds across the globe will be considered. Applicants from communities underrepresented in science, or with a strong history of service to these communities, are particularly encouraged. Candidates applying at the Associate or Senior level should demonstrate the potential to take a leadership role in the Plum Island Ecosystems Long-Term Ecological Research program (pie-lter.ecosystems.mbl.edu/) or the Semester in Environmental Science (mbl.edu/ses/). We seek candidates with diverse areas of research expertise, including, but not limited to, biogeochemistry and its controls, trophic interactions, ecological modeling, and community and ecosystem ecology. Top priority will be given to candidates demonstrating interest in conducting research within the broad context of global climate change and other anthropogenic influences on the coastal zone.

The Ecosystems Center (mbl.edu/ecosystems/) was founded four decades ago to investigate the structure and functioning of ecological systems and predict their responses to changing environmental conditions. The current faculty is highly collaborative, with strength in biogeochemistry, ecological modeling, microbial ecology, microbial dynamics, plant-soil interactions, coastal processes, and adaption to life on land (mbl.edu/ecosystems/faculty/). Ecosystems faculty also collaborate with other groups at MBL with expertise in molecular evolution, functional genomics, microbial diversity, developmental and regenerative biology, bioinformatics, and advanced imaging techniques. MBL's initiative in coastal ecosystems ecology complements other strategic initiatives at MBL involving microbiome research, the development of aquatic organisms as new research tools, and advanced imaging and image analysis. The MBL is an affiliate of the University of Chicago and an Equal Opportunity/Affirmative Action employer committed to diversity. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability, gender identity, sexual orientation or protected veteran status.

Qualifications:

Applicants must hold a Ph.D. (or equivalent advanced degree) in a relevant field. The successful candidate will demonstrate an interest in collaborative, interdisciplinary work, as well as a strong potential for establishing a vigorous extramurally supported research program that can complement existing areas of strength.

Applications should be submitted at **https://academicjobsonline.org/ajo/jobs/15843**

Applications received by March 15 will receive full consideration; however, applications will be accepted until the position is filled. Inquiries about the position should be directed to Dr. Anne Giblin, Chair of the Search Committee **(agiblin@mbl.edu).**

Northeastern University

Assistant/Associate/Full Teaching Professor - Electrical and Computer Engineering - Robotics

About the Opportunity:

The Department of Electrical and Computer Engineering at Northeastern University invites applications for Assistant/Associate/Full Teaching Professor with a focus on Robotics

Responsibilities:

Northeastern University's Department of Electrical & Computer Engineering seeks outstanding candidates for the position of Assistant/associate/full teaching professor with a focus on Robotics. This is a full-time, benefits-eligible, non-tenure-track position. Appointments are made on an annual 8-month basis, with salary commensurate with experience. The position of Assistant Teaching professor entails educational interaction with students in roles including, but not limited to, traditional instruction (lecture courses, lab courses), curriculum development, and student advising. The main responsibility of this position is teaching courses related to robotics, including kinematics, dynamics, and control of robots, design of microprocessor-based control systems, sensory devices, output actuators, numerical methods, state estimation, control, perception, localization and mapping, motion planning, and the ROS (Robotic Operating System) environment. Also expected to teach courses in embedded systems, digital logic design, computer organization and/or programming.

The annual teaching course load is six courses, with the potential for teaching more than one section of a course in the same semester, over Fall and Spring semesters. Courses may be at both the undergraduate and graduate levels.

Qualifications:

A PhD in Computer Engineering, Electrical Engineering, Computer Science, teaching experience, is required. Candidates should have demonstrated experience robotics and related subareas. At least 2 years' experience in teaching at the college/university level is recommended. Excellent written and oral communication skills are required. Industrial experience is desirable, but not required.

Application should include a cover letter, CV, teaching statement, 3 references. A sample syllabus from a previously taught class is optional but recommended.

Salary Grade: FAC

Additional Information:

Northeastern University is an equal opportunity employer, seeking to recruit and support a broadly diverse community of faculty and staff. Northeastern values and celebrates diversity in all its forms and strives to foster an inclusive culture built on respect that affirms inter-group relations and builds cohesion.

All qualified applicants are encouraged to apply and will receive consideration for employment without regard to race, religion, color, national origin, age, sex, sexual orientation, disability status, or any other characteristic protected by applicable law.

To learn more about Northeastern University's commitment and support of diversity and inclusion, please see www.northeastern.edu/diversity

To apply, visit https://apptrkr.com/1784885

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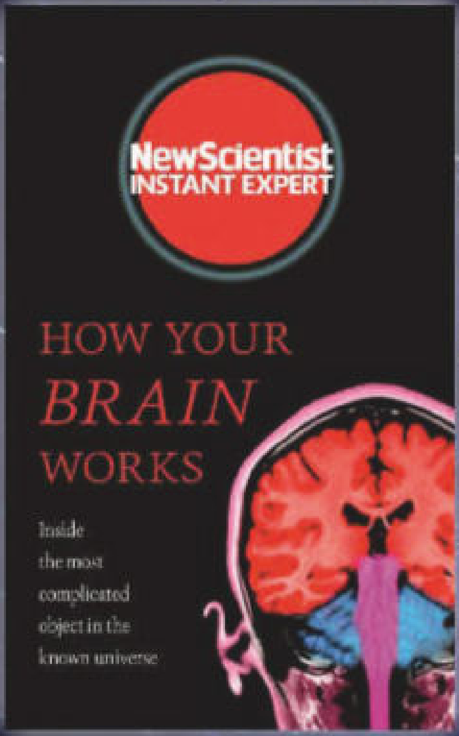
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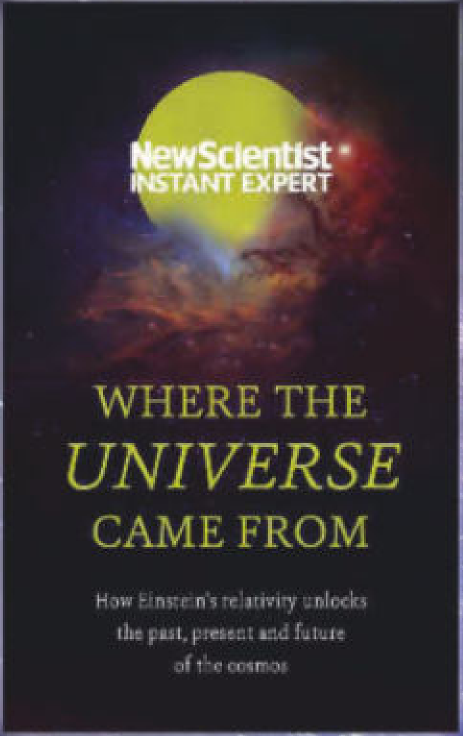
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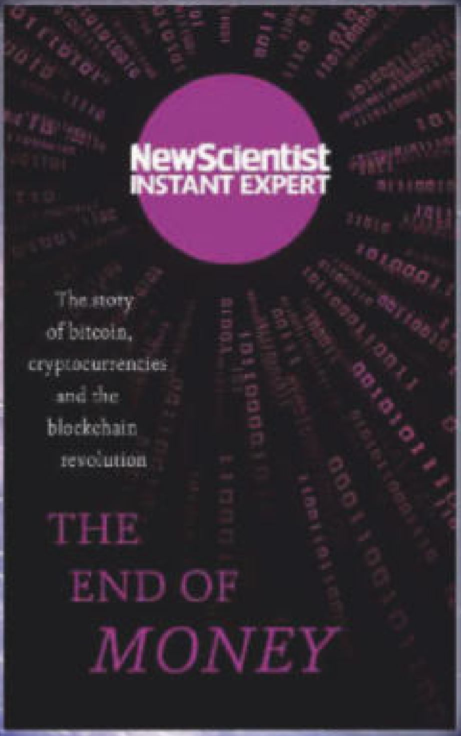
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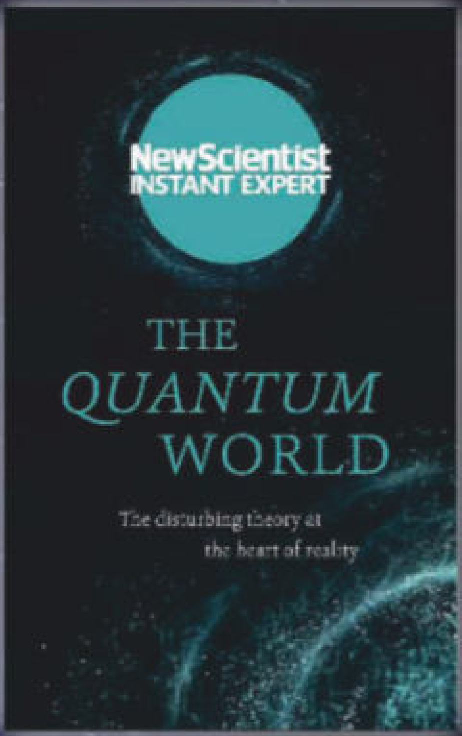
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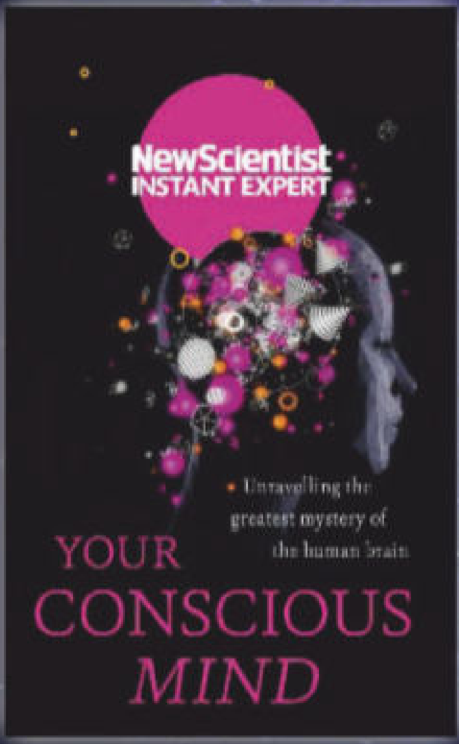
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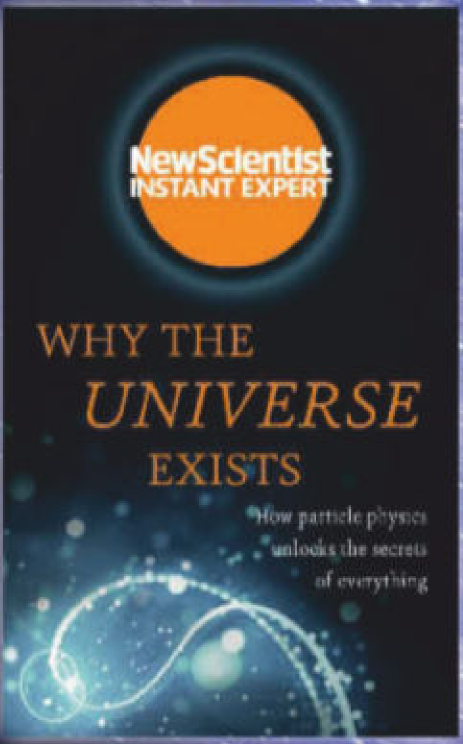
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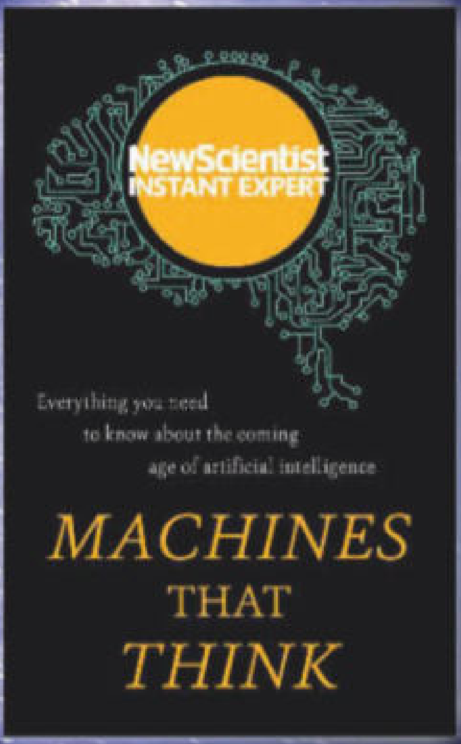
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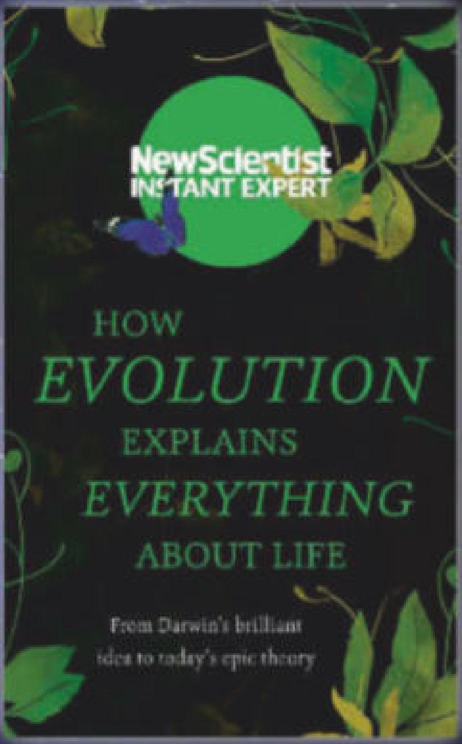
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The smell of rust, and radio interference: readers respond p54

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Kate Darling on how we feel about animals and robots p56

Science of cooking Week 12

It's all about the stretch

It is easy and fun to make hand-pulled noodles if you understand how gluten works, says **Sam Wong**

Sam Wong is social media editor at *New Scientist*. Follow him @samwong1

What you need

Flour
Salt
Vegetable oil
Garlic
Spring onions
Sichuan pepper
Chilli flakes
Soy sauce
Chinese black vinegar

Next week

Pastry: gain mastery over this kitchen staple by understanding how fat and water interact with flour, and make a rhubarb tart

SIMON REDDY/ALAMY

Science of cooking online
All projects are posted at
newscientist.com/cooking **Email: cooking@newscientist.com**

MAKING noodles by hand is an art, practised most spectacularly by chefs in China who pull, twist and stretch a single piece of dough into hundreds of strands as diners watch. It takes years to master this, but some types of noodle are pretty easy and fun to make at home. One is biang biang noodles, which originated in Shaanxi province in central China.

Hand-pulled noodles are testament to the stretchy and springy properties of gluten, a mix of two groups of wheat proteins: glutenins and gliadins. When flour and water combine, glutenins link into a large network, while tightly folded gliadins bond weakly to glutenins and to each other.

Dough is stretchy because the gliadins act like ball bearings, allowing glutenins to slide past each other. It is elastic because coiled stretches of protein resist deformation and pull back to their original shape. To make noodles, you need the gluten to be strong enough that you can pull the dough without it breaking, but not so strong that it won't stretch.

One consideration is the protein content of the flour. Plain flour has around 10 per cent protein and strong bread flour has up to 15 per cent. I have made noodles with both, but the plain flour dough was slightly easier to work with.

To make noodles for two, take 300 grams of flour and mix in half a teaspoon of salt. Salt strengthens the gluten network because it interacts with charged portions of the proteins, helping them bond.

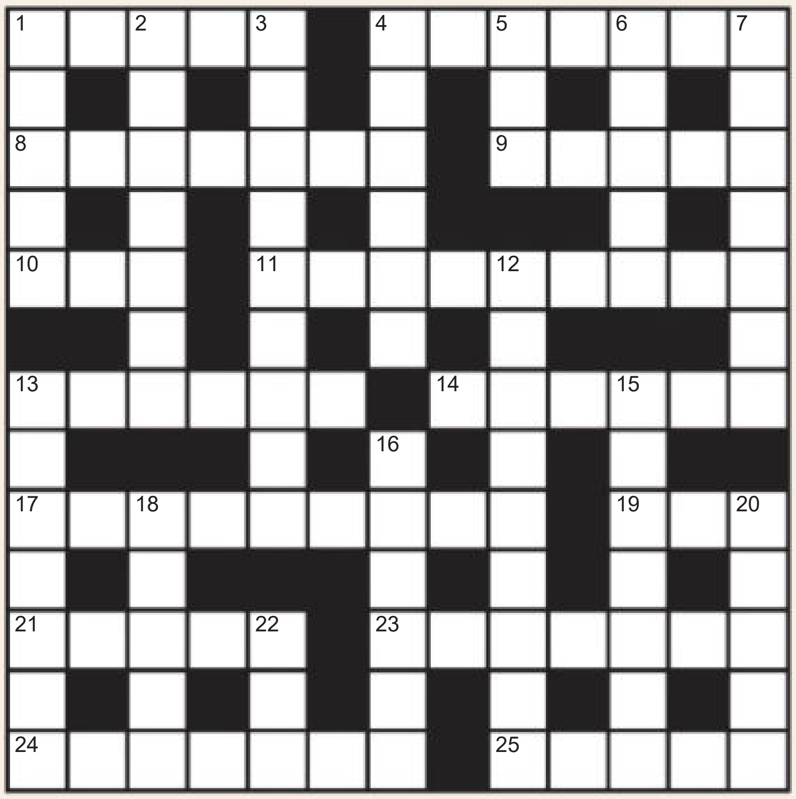
Mix in 150 millilitres of water with your hands to make a fairly stiff dough. Cover and leave for half an hour for the flour to hydrate and start forming gluten. After this, knead the dough for 2 minutes, then divide it into six pieces and roll each into a log shape. Coat them with oil, then cover and leave for 2 hours. In this time, protease enzymes will break down the gluten a bit, making the dough softer and more stretchy.

Meanwhile, prepare the toppings: minced garlic and spring onions, ground Sichuan pepper and chilli flakes.

After 2 hours, get a large pot of water on the boil and flatten a log of dough into a rectangle with a rolling pin. Take a chopstick and press it lengthways down the middle of the rectangle to create two strips that are still joined together. Pick them up and, holding each end throughout, stretch them horizontally, moving your hands up and down as you pull to make the noodles slap on the work surface. Aim for metre-long noodles. Then pull the two strips apart.

When you have prepared half the noodles, cook them for a minute and then remove from the water. Prepare and cook the rest. Now heat 5 tablespoons of oil until almost smoking. In a bowl, pile the toppings on the noodles, then pour over the hot oil. Add 2 tbsp soy sauce and 2 tbsp Chinese black vinegar, then mix until all the noodles are coated. ▮

Cryptic crossword #27 *Set by Sparticle*



ACROSS

1/4 Australian town rings special rock (5,7)

8 Split ossifying party after young fringes break away (7)

9 Showcased cabbage lox sandwich (5)

10 Necklace of Klein bottles (3)

11 Put gun away after cheery line (9)

13 Packed with seamen, say, which sounds rude (6)

14 Shoot up faster, surprisingly (6)

17 Obscure quote absorbs frazzled don (9)

19 Hair product gives eyelashes luxuriance from the start (3)

21 Some grown-ups confess (3,2)

23 Plucked brow in a way to show pride (7)

24/25 Peer spilled gin tumbler through which 1,4? (7,5)

DOWN

1 Terrible when honest leader disappears (5)

2 Give confidence to One Direction's lead singer beginning to process anger (7)

3 Corrupt a nice pure soul who likes a good time (9)

4 Connects and audibly penetrates (6)

5 Right back crushing leading infielder's bone (3)

6 Darkness almost upon us squares (5)

7 Oddly supple desire to overspend (7)

12 Tool for shaping jewellery covering (9)

13 See 20

15 Mathematical subfield is honestly a garble (7)

16 Bizarre original loss of an extraction plant (3,3)

18 In fog, no canoes go up river (5)

20/13 Whimsical writer of *Hamilton*, say, raps song (5,7)

22 Bar alternative used for quantum function (3)

Answers and the next quick crossword next week.

Quick quiz #43

1 The five most abundant chemical elements in the universe are hydrogen, helium, oxygen, carbon and which other?

2 On which bridge in northern England is the design of Sydney Harbour Bridge based?

3 More than 70 per cent of the world's pistachios are produced by Iran and which other nation?

4 What day followed Wednesday 2 September 1752 in England and Wales?

5 What does a phlebotomist do?

Answers below

Quick Crossword #53
Answers

ACROSS **1** Hawthorn, **5** The Sea, **9** Xenolith, **10** Floret, **11** Existenz, **12** Iceman, **14** Alkaliweed, **18** Thrombosis, **22** Rotate, **23** Stunsail, **24** Aye-aye, **25** Magic eye, **26** Statto, **27** Apollo 13

DOWN **1** Huxley, **2** Win-win, **3** Halite, **4** Retinal rod, **6** Helicoid, **7** Strimmer, **8** Actinide, **13** Marie Tharp, **15** Star Wars, **16** Erythema, **17** Amethyst, **19** Infill, **20** Make do, **21** Alien 3

Quick quiz #43
Answers

1 Neon, comprising 0.13 per cent of the universe. Large amounts of it are made in stars through the alpha process of nuclear fusion
2 The Tyne Bridge in Newcastle
3 The US
4 Thursday 14 September 1752, thanks to the switch from the Julian to the Gregorian calendar to catch up with the sun
5 Draws blood for medical purposes

Puzzle *set by Katie Steckles*

#51 Birthday candles

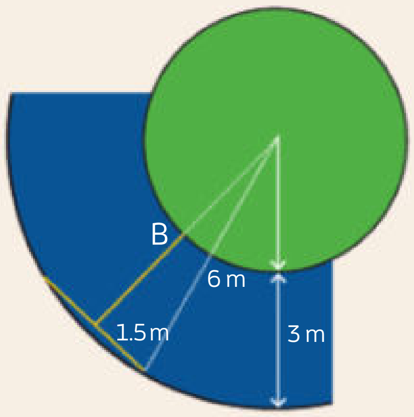
It is Tom's 7th birthday and he has a cake with seven candles on it, arranged in a circle – but they are trick candles. If you blow on a lit candle, it will go out, but if you blow on an unlit candle, it will relight itself.

Since Tom is only 7, his aim isn't brilliant. Any time he blows on a particular candle, the two either side also get blown on as well. How can Tom blow out all the candles? What is the fewest number of puffs he can do it in?

Answer next week

#50 Crossing the river
Solution

If Petal places one oar with both ends on the bank, it cuts off a sliver of the bend. Putting the other paddle perpendicular to this will let Petal skedaddle over the paddles and pick up Gretel's kettle.



You can demonstrate this using Pythagoras' theorem: $B^2 = 6^2 - 1.5^2$ meaning $B = \sqrt{(6^2 - 1.5^2)} = 5.81$
So the point where the oars meet is 5.81 metres from the island's centre, or 2.81m from its edge. We are told the oars are just short of 3m, so they should be long enough – and hopefully strong enough too.

TOP: GUZALIA FILIMONOVA / GETTY IMAGES

Our crosswords are now solvable online
Available at newscientist.com/crosswords

D-I-WHY

It's heartening to see so many calm responses to the coronavirus outbreak. For example, ever-resourceful citizens of the US have been making their own hand sanitiser from budget spirits. After numerous customers tweeted about this bright idea, vodka brand Tito's patiently responded to each of them, advising that hand sanitiser should contain at least 60 per cent alcohol, so its 40 per cent proof product doesn't meet the standard.

In Australia, people have been calmly preparing for the absolute worst-case scenario: finding themselves out of toilet paper. Most of the country's supplies are made locally, but a rumour of decreased production in China seemed to send panic through some communities, resulting in shops with empty shelves.

Rolls were reportedly being sold for hundreds of dollars online. Luckily, the Australian press can be relied on to help in a crisis. The *NT News* came to the rescue by printing an eight-page pull-out "complete with handy cut lines, for you to use in an emergency". Eager to match this example, Feedback willingly proffered itself for this purpose, but sadly our editor insisted that we should still print some words on the page, even if it is to be used for personal hygiene. Please don't hesitate to tear out this page if you find yourself in need.

Take a bow

In the UK, of great concern to the public is how to make formal greetings once shaking hands has been deemed too dangerous. The England cricket team has opted for fist bumps, but as this still involves hand-to-hand contact, it doesn't seem like a vast improvement.

Elbow bumps are another popular option, but one whose wisdom seems questionable when you remember that we are also being advised to cough and sneeze into a bent elbow. Some are tapping feet, but having tried this out, we are slightly concerned that this could lead to a risk of losing one's balance and falling over.

You don't need to look far back in history to find some truly non-contact modes of formal greeting, such as the bow or curtsey, which might be more sensible.

Feedback recommends the "ner-ner" handshake, popular in school playgrounds, in which you extend an arm as if offering a handshake, but withdraw it at the last minute and wiggle your fingers in front of your face. Traditionally this is done with the thumb touching the nose, but touching one's nose is now a complete no-no, so a 2 centimetre gap is advisable.

Sum tweet

If we had a penny for every time a media pundit showed a shockingly poor grasp of numeracy, Feedback would have enough money to launch an expensive but highly ineffective run for president. Well, maybe not if you did the actual maths, but why let that stand in the way of a good point?

The latest example appeared in a segment on news channel MSNBC that drew attention to a tweet decrying the $500 million spent by Michael Bloomberg on his short-lived election campaign. "The US population is 327 million. He could have given each American $1 million and still have money left over," journalist Mekita Rivas tweeted. "It's an incredible way of putting it," said presenter Brian Williams, and on this point we agree wholeheartedly.

Mixed up advice

Thankfully, the media are being careful to get their facts straight on coronavirus advice. Having initially made an error in an article titled "Coronavirus: Nine reasons to be reassured", *The Guardian* quickly made a correction. "An earlier version wrongly stated that 'a solution of ethanol, hydrogen peroxide and bleach will disinfect surfaces'," it said. "It is dangerous to combine such substances. It now states correctly that 'a solution of ethanol, a solution of hydrogen peroxide *or* a solution of bleach' will disinfect surfaces." (Emphasis added.)

Twisteddoodles *for New Scientist*

What is your group's research about?
We discover interesting trivia to drop into conversation
Like "a cockroach can live for ten days without a head"?
Yes! That was Dr Simmon's best work!
Or "a pig's orgasm lasts for thirty minutes?"
Yes... That was Ian, we had to let him go
@twisteddoodles

Chemistry lessons might also be required at the BBC, which stated that the E10 fuel being considered to help the UK reduce CO_2 emissions "contains less carbon and more ethanol than fuels currently on sale". It might be more eco-friendly still if boffins could work out a way to produce carbon-free ethanol. Thanks to James Olver for bringing this to our attention.

Sty phone

Surreal news from North Yorkshire, UK, where a fire broke out on a farm after a pig swallowed a pedometer that was being worn by another pig. "After nature had taken its course, it's believed that the copper from the batteries reacted with the pigpens contents and in conjunction with dry bedding, ignited burning approx. 75sqm of hay," the North Yorkshire Fire and Rescue Service posted on Twitter.

We thought *New Scientist* was on top of the trend for wearable electronics, but this fad is more pervasive than we realised if even livestock are keeping track of their step count.

According to the fire service, the pedometer was being worn to prove that the pigs were free range. Feedback is a firm believer in animal welfare, but we are unsure whether instilling them with our exercise-tracking obsession is entirely helpful in this regard. We shouldn't scoff though – pigs have long been associated with apple products, and perhaps this individual is a twirly adopter. ▮

Got a story for Feedback?

Send it to New Scientist, 25 Bedford Street, London WC2E 9ES or you can email us at **feedback@newscientist.com**

The nose knows

Rust doesn't appear to release molecules into the air. So why does it have a smell?

Stefan Badham
Portsmouth, Hampshire, UK
Rust is another name for iron oxide. It occurs when iron is oxidised by being exposed to oxygen in the presence of moisture.

Although not obvious in dry air, rust's odour can be detected in damp conditions, when oxidisation is most likely to occur. Rust's odour is carried in airborne water droplets, and this is how it is transmitted to our senses. Human blood, which also contains water and iron, has a smell similar to rust.

David Muir
Edinburgh, UK
This is an olfactory illusion. Smell a dry metal paper clip. Lick your fingers and give it a good rub, then smell it again.

Ferrous ions, Fe^{2+}, form when skin touches the iron in rust, especially if skin is moist. These ions react with fatty compounds called lipid peroxides, present on your skin, to produce carbonyl compounds such as 1-octen-3-one. This has a smell we associate with metal. It is skin chemicals that produce 1-octen-3-one, not the iron or rust.

Researchers at the Virginia Polytechnic Institute and State University have shown that the amount of 1-octen-3-one increases as skin is rubbed with increasing concentrations of Fe^{2+} solutions.

Blood, containing Fe^{2+}, also gives a metallic smell when smeared on our skin. This gives rise to the "coppery" odour of blood, but the smell is actually derived from the skin's fatty chemicals.

Luce Gilmore
Cambridge, UK
While metals and metallic oxides are unlikely to have any odour, the same isn't true of organic-acid salts of metals. This is what is responsible for the bitter smell of bronze coinage, for instance, on which copper forms salts with lactic acid from human sweat.

BILL OXFORD/ISTOCKPHOTO/GETTY IMAGES

What is the deposit found on clean windows after rain?

This week's new questions

Rainy residue **My windows are cleaned every four weeks, and normally stay sparkly. But recent heavy rain has left a deposit on them. What is it?** ***Stuart Fairful****, Dunfermline, Fife, UK*

Viral survival **How long do viruses like cold, flu and coronavirus survive outside the body? What factors affect this?** ***Douglas Fairchild****, Two Harbors, Minnesota, US*

Radio gaga

If I use my cellphone then put it next to my bedside radio, the radio starts to make odd sounds through the speaker. What's going on?

Eric McAndrew
Capel, Western Australia
Your cellphone is a radio transmitter. It periodically sends signals to the phone network to let the network know it is still there.

If the phone is near a radio, the signals, which are pulses of energy, penetrate the radio and you hear these as odd sounds. The only solution is to leave the cellphone and clock radio a few metres apart.

Jens Ole Madsen
Neu-Ulm, Germany
The sounds are electromagnetic disturbances induced in the audio system of the radio when the phone is transmitting. This isn't limited to devices equipped with a radio receiver – the same sounds can be heard in an mp3 player close to a mobile phone. The frequency used by the phone doesn't disturb radio reception, it just affects the audio lines of the device.

The most typical sound is generated during a location update. This is needed so the phone network knows which base station should contact the phone in case of an incoming call.

The complete location update, as defined in the Global System for Mobile communication (GSM) specification, consists of bursts of transmissions with set timings between them, and this gives a characteristic series of sounds.

Later mobile phone standards use a different form of location update, so you will hear this sound only when the phone is using the GSM network, usually because of lack of coverage on the 4G network.

Richard Hind
York, UK
The same effect allows wireless charging of small electrical devices like toothbrushes. What you are hearing is the burst of phone signals at gigahertz frequencies being modified by the electronics in the radio.

Electromagnetic interference can be picked up from other devices, too, such as the motors in vacuum cleaners and power drills. Electric guitar players are all too familiar with this effect: if they stand next to any device with a conventional transformer there is a loud hum through the amplifier their guitar is plugged in to.

Computers are another source of electromagnetic interference because the processor is operating at gigahertz frequencies too. The power cable can act as an antenna. It is possible to use something called a ferrite choke to suppress this – that's what the cylindrical object you often see on power cables for laptops is.

John Childs
Durham, UK
Radio manufacturers try to minimise sensitivity to "out of band" frequencies, but a strong signal can cause a response.

In analogue times, this sometimes resulted in hearing the actual audio content of radio chatter, often on public PA systems, which were sensitive to stray radio frequency emissions. Hearing what was being broadcast on taxi radios, for instance, wasn't uncommon, and could be amusing or embarrassing depending on the words being said, although normally only the nearby signal was detected so one half of the conversation was missing. ▮

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Kate Darling studies how we interact with robots and form emotional connections to them. There are a lot of parallels with our treatment of domesticated animals, she says

So, what do you do?

I'm a researcher at MIT, where I study human-machine interaction from a social, legal and ethical perspective.

When humans interact with machines like robots, they often seem to develop an emotional connection. Why?

We are very social creatures and we tend to subconsciously treat robots like they are alive, even though we know they are just machines. Part of this comes from our tendency to anthropomorphise, i.e. to project human traits, motivations and behaviours onto non-humans, like our pets. We do this in order to make sense of the world around us. Robots move around in our physical space in a way that seems to have agency, so we are hardwired to perceive them more like a living thing than an object. Plus, some robots are intentionally designed to look alive or mimic social cues. When a robot behaves in a way that we recognise and empathise with, we can become emotionally attached.

Do we engage more with robots that look human?

A lot of it is about projecting ourselves, so designing a robot to mimic certain aspects of human emotion can make a robot engaging. But the robot doesn't necessarily need to look human. R2-D2 from *Star Wars* only communicates through beeps and boops, yet he has more fans than his humanoid partner C-3PO. In fact, more than 80 per cent of people will name their robotic vacuum cleaner, which isn't even designed to be social.

How did you end up working in this field?

I have always been passionate about studying how systems change human behaviour. Plus, I love robots, and now I get to play with them every day.

Your upcoming book is about animals. Are there parallels with robots?

Yes. The book looks at our history of domesticating animals for work, weaponry and companionship, and draws out lessons on how to integrate robotic technology. There are many parallels to how we could be thinking about robots, from workplace use to responsibility for harm to social relationships.

How has your field of study changed in the time you have been working in it?

A decade ago, people viewed studying human-robot interaction as fringe. Now that robots are coming into workplaces, households and public spaces, the importance of understanding their social impact is more salient and the field is growing. I'm glad people no longer think I'm weird!

As a child, what did you want to be when you grew up?

I wanted to be a singer, which my husband thinks is very funny.

What scientific development do you hope to see in your lifetime?

Better breast-pumping technology.

What's the best thing you've read or seen in the past 12 months?

Everything by *The Washington Post* columnist Alexandra Petri.

If you could have a conversation with any scientist, living or dead, who would it be?

Katie Mack, a theoretical astrophysicist who has inspired people all over the world to be interested in science. I would love to talk to her about how she taps into our wonder and excitement.

> "For hundreds of years, we put animals on trial for the crimes they committed"

Do you have an unexpected hobby, and if so, please will you tell us about it?

I love rock shows! My brother is in a European glam rock band called Bitch Queens.

How useful will your skills be after the apocalypse?

If the apocalypse is a robot uprising, very.

OK, one last thing: tell us something that will blow our minds…

For hundreds of years, we put animals on trial for the crimes they committed. There is even a movie, *The Hour of the Pig*, based on a true story and starring Colin Firth as a lawyer defending a pig. ▮

Kate Darling is a research specialist at the Massachusetts Institute of Technology's Media Lab. Her book *The New Breed: What our history with animals reveals about our future with machines* (Henry Holt and Co.) is out in 2021

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